TECHNICAL EFFICIENCY AND TECHNICAL PROGRESS IN THE COLOMBIAN METAL-MECHANICAL SECTOR: 1977 AND 1986

by

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(1980)

SUBMITTED TO THE DEPARTMENT OF
URBAN STUDIES AND PLANNING
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
March, 1991

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ABSTRACT

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ABSTRACT

The focus of this research was to examine and quantify as accurately as possible the changes in productivity in two metal-mechanical industries. Through these changes in productivity we traced the changes in the relative efficiency of firms, and by comparing the movements of those firms defining best-practice production techniques we traced technical progress. The purpose of this study of efficiency and technical change was, first, to be able to evaluate firm economic performance, and second, to uncover what firm strategies made for success or failure in difficult market circumstances.

Using the tools of efficiency measurement, specifically the deterministic production frontier, we examined patterns of firm efficiency to test hypotheses regarding the relative efficiency of firms in developing countries with long histories of import substitution. While we found substantial scope for efficiency improvement in 1977 and 1986, we found no systematic relationship between technical efficiency nor technical progress and firm size. Only in the case of very small firms did we find evidence of capital indivisibilities given the number and variety of metalworking machines required by the production technology in the sector.

We found a range of plant scales consistent with technical efficiency and that within a given technology (what is referred to as the ex-ante choice) there was flexibility allowing a range of factor proportions (ex-post) and types of plant organization. Our firm sample did not support the popular myth of small labor-intensive firms or large capital-intensive ones. Small firm entrepreneurs were able to maximize the use of their capital by subcontracting work to their employees, large firm entrepreneurs accomplished the same by diversifying their product line.

By 1986 with the maturing of both industries and the trial by fire represented by the recession, the general level of managerial know-how had increased, and more specific production-related capabilities and efforts became important. Most important, however, were the difficulties in obtaining material inputs in the second survey year. Import restrictions resulted in firm stockpiling. This practice imposed real efficiency losses on all firms regardless of size or factor proportions and took Colombian firms further away from the ideal of the flexible specialization model and its reliance on just-in-time inventories. Another obstacle to achieving this ideal was the firms' survival strategy based on cutting labor costs. The recession provided firms an opportunity to reduce employment as well as labor's share without complementary efforts to increase labor productivity

These trends are particularly worrisome because productivity gains across survey years were strongly associated with firms' relative technical efficiency in the initial survey year.

This suggests that static efficiency in one period strongly affects dynamic productivity gains in the future. We would expect, therefore, that a continued preoccupation with cost-cutting to the exclusion of real technological efforts will slow productivity gains in industries still delaying investment in both capital and labor

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ACKNOWLEDGEMENTS

I would like to thank the members of my thesis committee, Karen Polenske, Jerry Rothenberg, and Kirk Bozdogan for their moral and intellectual support. My husband, David, and our friends at Dartmouth College and Washington D. C. provided the daily doses of encouragement that kept me working on the thesis. I am particularly grateful to Mariluz Cortes of the World Bank for sharing her 1977 survey data and working papers, and to the Colombian entrepreneurs who granted me interviews and gave me an appreciation for the concepts I was trying to measure. Any errors and omissions are entirely my own.

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CHAPTER 1

THE PROBLEM OF TECHNOLOGICAL DEVELOPMENT

The problem of how to foster technological development is a new one and not wholeheartedly recognized. For a long time it has been considered a corollary of economic growth in developed countries whose wealth sustained the innovative process. Solow (1957) and Denison (1962, 1974) quantified the contribution of technology to economic growth and today their results, which attribute 40% to 90% of the growth in gross output to technological change, are the primary evidence for arguments supporting loan packages for science and technology in developing countries.

Such arguments reflect a change in thinking about technology. Technological progress is no longer a by-product of economic growth but a necessary condition; it is no longer a simple matter of importing capital goods embodying state-of-the-art technologies. Decades of development efforts have shown the difficulties of initiating self-sustaining growth in which capital-deepening brings embodied technological progress and unleashes its disembodied equivalent--jointly, improved machinery and labor bring about productivity benefits greater than the sum of their individual contributions. From the traditional view of technological change as an exogenous shock to a steady state, it has become a phenomenon endogenous to the production process.

This new focus on technology reflects the achievements of semi-industrialized Less Developed Countries (LDCs) who have built an industrial infrastructure in which the easier initial gains of import substitution in light industry have been exploited. Now these countries face the problem of industrial deepening and few have internal markets large enough to support the costs of import substitution strategies. Even in the largest developing countries, the inward-oriented development model appears to have outlasted its usefulness. In Latin America the 1980s has been popularly labelled the lost decade. The globalization of capital brought home the pressures of world supply and demand. Most of these countries still are trying to recover from the repercussions of the oil crises in the

1970s and the global recession and debt crises in the early 1980s . The Keynesian tools of government intervention proved ineffective against stagflation and mounting fiscal and balance-of-payments deficits. Instead, for solutions to external sector problems, we now look to the example of the export-led development model of the Asian Newly Industrialized Countries (NICs). For solutions to internal sector problems, increasingly we look to the market and the private sector to allocate resources efficiently. Where the development economist saw market failure arising from institutional deficiencies, externalities, or market myopia, now he/she discovers price distortions.

In the late 1970s, development agencies like the World Bank and the Inter-American Development Bank began to examine the claims of those espousing the need to foster capital goods production in LDCs (Stewart, 1976 and 1979; Mitra, 1979; Pack, 1980; Research Program in Science and Technology, Economic Commission on Latin American/ United Nations Development Program/ Inter-American Development Bank). These claims held that an indigenous technology would avoid the inefficiencies of inappropriate imported technologies often associated with import-substitution development strategies. These analysts examined the requirements for successful promotion of infant industries, particularly capital goods. In trying to evaluate and quantify successful infant industry promotion, they focused increasingly on firm efficiency and the patterns of productivity change.

Although developing country planners continued to debate selective promotion of capital goods, the world recession shifted their attention towards the more immediate problem of making existing industries more efficient. The move to trade liberalization, a central feature of structural adjustment programs and a condition of further concessionary credit, added more pressure in this direction. Accordingly, Dahlman and Westphal (1982, p. 106) of the World Bank coined the phrase "technological mastery" defined as the continuing efforts of firms to assimilate, adapt, and/or create technology. The old paradigm of technological transfer focusing on capital imports has been replaced. Instead of a passive transfer, the current paradigm centers on active efforts to assimilate and adapt existing technologies. Instead of focusing on major innovations, this view traces the incremental and cumulative improvements in efficiency that make up the bulk of productivity gains. The first order of business has become the measurement of efficiency and productivity.

If we could identify the types and potential causes of firm inefficiency, this information would guide the formulation of policies to correct it. This exercise would be important not only in the static context of a given time period, but also in the dynamic context of productivity changes through time. A study of the same firms under different conditions would suggest how firms adapt and evolve, helping us to sort out the complex set of technical, human, and structural factors at the micro and macro levels which impinge upon the process of technological development.

In the following chapters, we examine the economic performance of a group of Colombian metal-mechanical firms producing agricultural and industrial kitchen equipment. The 1977 firm survey by Cortes, Berry and Ishaq (1985) provided the base year data to our follow-up survey of these same firms in 1986. The first year coincided with a period of strong economic growth, while the latter represented a period of recovery from a long-lasting recession. These differing macroeconomic conditions allow us to examine how entrepreneurs make decisions about ways to improve efficiency and initiate technological efforts in the unstable macroeconomic context, which characterizes present day Latin American economies. We examine how firms, representing a nascent capital-goods sector, respond to fluctuating demand in an environment where they are unevenly shielded from competition and the threat of a rapidly advancing technological frontier. We study how they trade-off technological efforts with austerity measures geared toward simple survival.

ACHIEVING TECHNOLOGICAL MASTERY: EFFICIENCY AND TECHNOLOGICAL PROGRESS

This new preoccupation with efficiency has allowed a more meaningful approach to the problem of technological development. The accelerating pace of the technological frontier has forced the industrial restructuring of industries in both center and periphery, laying aside the orderly stepwise progression envisioned by product life-cycle strategists. Westphal, Rhee, Kim, and Amsden (1984) have shown the possibilities for LDCs to achieve competitiveness even in capital goods exports. This example emphasizes efficiency in production as the primary prerequisite for participation in a demanding international market. However, efficiency has taken on a dynamic dimension in the race to incorporate the latest productivity-enhancing technologies.

Increasingly as more LDCs try to move out of the 1980s recession and cope with greater protectionism in traditional export markets, they are looking away from policies oriented toward exploiting their comparative advantage in low-wage labor and toward those fostering technological mastery. This mastery is sought by means of selectively carving out a market niche where domestic value added may receive favorable terms of trade. This broad policy guideline is yet to be worked out in detail and implemented through concrete changes in trade regimes and industrial development strategies. Although the terminology and rhetoric are different, the objective remains the same--to be able to exploit comparative advantage and realize the gains from participation in international trade, that is, access to a wide variety of efficiently produced goods and services.

Notwithstanding the current liberalization prescription, this policy calls for a delicate balance involving the mix, timing, and targeting of import-substitution and export-promotion incentives. Studies of the Asian export economies by authors such as Yusuf and Peters (1985), Westphal (1982), Westphal et al. (1984), and Dahlman et al. (1985) provide evidence of the need for this calibration all along the development process.

Although the Asian NICs are used as examples to show the folly of maintaining import substitution policies, their experience confirms the potential gains from the old paradigm based on government dirigisme. Their success in state planning demonstrate the possibilities of economic management and rapid capital accumulation. In contrast, most Latin American countries including Colombia which we focus on later, have clung to import substitution strategies thereby preserving a structure of protection no longer consistent with their evolving industrial structure.

Achieving technological mastery in a particular production process at a given point in time is no longer sufficient in a dynamic context of constantly changing technologies and global financial markets. LDCs aiming to become a low-wage production platform for developed countries are warned that such a strategy provides only static gains and at best represents a first step towards moving up the hierarchy of a shifting international division of labor. In the case of semi-industrialized LDCs the problem is seldom the lack of skilled labor (though in certain newer fields there are shortages), but rather the efficient use of this labor domestically. LDCs will have to master the technologies to produce new and/or better products in specific market niches in order to stay ahead of protectionist measures adopted to counteract the adjustment to structural change in a global economy and to create high value added activities that will help to sustain a higher standard of living.

Policy makers' attention to technology issues reflects a greater optimism in the international context. Technological change in process engineering (i.e., improvements in the efficiency of the production process) can breathe new life into older segmented markets by reducing barriers to entry and introducing greater competitive discipline in the various markets. Technological change in product engineering in the form of new products can similarly resuscitate demand and reverse market saturation. Certainly, these potential opportunities arise from a perception of technological progress at a small scale. A specific case in point is the recent popularity of flexible technologies and manufacturing systems designed to defy the rigidities of traditional mass production systems and their associated bureaucratic corporate structures (Piore and Sable, 1984). New technologies embodied in programmable machinery promise to pave the way for an industrial organization where small-scale firms can be competitive. Competitiveness is becoming increasingly associated with firms' flexibility and adaptability to changing market conditions.

There are also internal pressures to promote technological development. Not unlike the situation in developed countries, LDC industrialists are also split between waving the banner for greater competitiveness, which requires efforts in adapting and creating new technologies, and putting up trade barriers to insulate the internal market from the creative destruction enveloping international markets. For LDCs, this battle among constituencies is particularly difficult, considering a long history of inward-looking development strategies. In most countries affected by the early 1980s recession, industrial restructuring has centered on reducing wages to regain competitiveness. Strategies based mainly on wage reduction, however, are short-term palliatives that cannot replace active and continuing efforts to improve total not just capital or labor productivity.

When analysts such as Merhav (1969), first examined the issue of technology in LDCs, they translated Schumpeter's notion of creative destruction into a vicious cycle of technological dependency. The innovative entrepreneur, whose inventiveness was fueled by the profits to be derived from being first in the market, was stifled by the monopoly of technology creators and providers in developed countries. Still, there are no data to provide evidence of innovation in LDCs. It is no wonder that Schumpeterian approaches, such as those by Kamien and Schwartz (1982), focus exclusively on developed countries. Using the methods of optimal control theory these authors model the competitive conditions most likely to induce firms to innovate. They use R&D expenditures as a proxy to measure technological efforts and the tendency is to focus on larger firms for which data on patents and other indicators of innovation are available. Nevertheless, even these analysts recognize that these indicators of innovation and technological effort may represent only imperfect proxies of the phenomena they are trying to measure.

CASE STUDY FOCUS: THE COLOMBIAN METAL-MECHANICAL SECTOR

The metal-mechanical sector in Colombia is the focus for this case study. This sector is the precursor and foundation for a capital-goods sector, whose role is to embody and diffuse that technology best reflecting the nation's relative factor proportions. In the short and medium term, competitiveness in the international market will depend upon LDCs' capacity to master, assimilate, and adapt imported technology. Without some domestic production, however, it is argued, even adaptation of foreign machinery is limited to repair work. In the long term, domestic capital-goods production is necessary to internalize within the economy the little understood, but much desired, process of continual generation of productivity enhancing improvements and innovations. If Colombian producers of capital goods can achieve technological mastery, the promise of even greater productivity gains from user industries bodes well for the country's future economic and technological development.

Rosenberg (1976) provides a dramatic example of the metalworking sector's potential role in economic and technological development. Citing the historical evolution of metalworking industries in the 19th century, he traces their role in generating, embodying, and diffusing technological knowledge. Responding to user specifications, metalworking firms embodied productivity-enhancing innovations in machinery and equipment. In addition, through their own product and process innovations, they produced more cost-effective machinery, which enlarged the user market, promoted specialization, imparted capital savings, and diffused technological improvements throughout the economy. Furthermore, the lumpiness or indivisibilities associated with capital equipment forced a change of scale in user industries, thereby creating economies of scale. As both input and output to a variety of production activities, product and process innovations in metalworking industries set off a cumulative chain of technological improvements through backward and forward linkages.

Considering the potential benefits of domestic capital-goods production, it is no wonder that this sector is considered a target for selective infant industry protection. Also, the sector's industrial organization requirements offer promise to semi-industrialized LDCs. The industrial structure of this sector in developed countries is characterized by small and medium-scale firms linked through a complex system of specialization (Rosenberg, 1976). Although this places great demands upon interindustry transactions in terms of the availability, variety, and quality of inputs, it also presents an opportunity to increase the roundaboutness of production and stimulate greater integration of the industrial structure. As a result, along with capital-goods production, LDCs such as Colombia and Brazil are experimenting with subcontracting banks or exchanges to bring together producers of linked industries (Teubal, 1987).

Moreover, in the case of capital goods, location is particularly important. For LDC firms in these industries, a significant portion of their production is targeted toward custom-made orders that reflect the economic base of their region and its industrial specialization. Not withstanding the globalization of production, there is broad scope for national and regional specialization in a high-value added market niche for capital goods (Chudnovsky and Nagao, 1983).

Early in the 1970s Colombia began to turn to an outward-looking development model by providing export incentives, reducing quantitative restrictions, and lowering tariff levels. According to neoclassical interpretations espoused in World Bank reports (1983,1984), this led to the high rates of growth later in the decade, but others such as Adda (1986) argue it also led to greater exposure in the international recession of the early 1980s. Since then, Colombia, like other LDCs in Latin America, has been recuperating from this long-lasting recession and forging industrial development plans based on competitiveness, productivity, and technology.

Colombia may be considered typical of middle-income semi-industrialized countries. Its economic performance does not stand out as exemplary, but neither does its debt or unemployment situation stand out as a particularly acute problem in comparison to other LDCs. As such, it is a good country to use to trace the impacts of austerity, shifting trade and industrial incentives, and changing policies toward fostering technological mastery. In addition, Colombia's macroeconomic policy has been similarly influenced by the current demands of international lenders toward structural adjustment and market liberalization. Like other LDCs, it continues to entertain what may be competing policies based on the implicit belief in the ability of government to direct and foster technological development.

MEASURING EFFICIENCY AND TECHNICAL PROGRESS

In our attempts to measure efficiency and technical progress we concentrate initially on Solow's (1957) total factor productivity (TFP) model, which quantifies this complex phenomenon by focusing on productivity change. The TFP is derived as a residual and represents the changes in productivity unaccounted for by changes in factors. We also describe how analysts have improved TFP methods by looking into the problems of aggregation, the measurement of capital, and disequilibrium conditions. In addition to these improvements, we introduce the methods of efficiency measurement to account for yet another source of potential bias to TFP--errors in optimization. Together these measurement techniques lay the theoretical foundation for our empirical work based on firm-level survey data from Colombian producers of agricultural and industrial kitchen equipment.

Nadiri (1970), Stiglitz (1979), Katz (1980), Moore (1983), Rosenberg and Frischtak (1985), and Fransman (1986) have criticized TFP methods for underestimating the complexity of the technological processes underlying productivity change. They argue that the conceptualization of these processes as a mechanical and exogenous shift of the production function is an extreme simplification. These methods, claim critics, are part of the old view of technology, which excludes its endogenous dimension and the impact of the production environment in inducing technical change under different forms of competition. The forces affecting this environment include those external and internal to the firm.

Externally, there is a host of policies that shape the production environment of firms by affecting the availability and cost of inputs as well as the market for outputs. From this vantage point focusing on economy-wide and sectoral trends, the World Bank has been examining the impact on productivity of inward versus outward development strategies (e.g., Krueger and Truncer, 1980; Nishimizu and Robinson, 1984). Nishimizu and Page, (1987; ongoing World Bank research project on Economic Policies and Productivity Change in Industry) have found TFP measures useful in sorting out the evidence with respect to infant industries. These authors suggest that TFP change should be interpreted broadly as movements toward technological mastery. They recognize that TFP measures also reflect industrial and plant organization, technical and managerial know-how, as well as changes in capacity utilization from short-term disruptions in the production process.

Internally, the firm's environment is regulated by its management which decides how to respond to external forces. Management sets the pace of technological mastery through its organization of production--decisions regarding the training of workers, the choice of technique, the replacement of capital. We would except that managerial ability is a key variable determining the efficiency and productivity of the firm.

Our empirical work examines these micro-level dynamics of technological mastery so often confined to a "black box." Our approach is based on neoclassical production theory, but complemented with TFP refinements and the techniques of efficiency measurement. TFP refinements guide us in the proper: (1) aggregation and measurement of inputs and outputs, particularly the peculiarities of capital, and (2) adjustment for violations of the TFP long-run equilibrium assumptions which are relevant in the case of LDCs. Efficiency measures recognize firms may not be operating on the production surface where output is maximized nor located on the cost-minimization point.

The firm's distance from the production surface, which denotes the input combinations maximizing output, give us a measure of the firm's technical efficiency. The distance from the cost-minimizing point, which denotes the appropriate input combination with respect to the relative prices of factors, gives us a measure of allocative or price efficiency. Scale efficiency refers to the appropriateness of the scale of operations of the firm given the structure and technological requirements of the industry of which it is part. In contrast to the firm-specific measures for technical and allocative efficiency, in the case of scale efficiency, when data are available, measurement usually follows the traditional production function analyses of returns to scale based on factor elasticities.

In our empirical work based on a limited but rich firm-level data set, we complement firm-specific efficiency measures, which focus on technical inefficiency, with information on firm size and factor proportions to examine the related problems of scale and allocative inefficiency. The industrial structure erected after decades of import substitution is often characterized by a few large and many small producers (Roberts, 1989). This bimodal size distribution of firms has fueled controversy regarding the efficiency of large versus small firms.

A priori arguments focus on why large or small firms should be the more efficient. Large firm proponents focus on economies of scale and failure of small firms to operate at the minimum efficient scale. They claim that these small firms survive, in spite of their scale inefficiency, because of limited import competition. Small firm proponents argue that because they save on scarce capital and make use of abundant LDC labor supplies, small firms are allocatively efficient. Their factor proportions reflect the relative scarcities in developing economies. In contrast, large firms who are the main beneficiaries of protectionist policies can be neither allocatively nor scale efficient--they are too capital-intensive and their scale of operations is too large for the domestic LDC market.

Both large and small firms are subject to technical inefficiency, but for different reasons. Without the incentives of competition, large firm managers fail to exert themselves sufficiently to produce the maximum with given inputs. Small firm managers have the motivation, but lack the training; even if they purchase inputs in the correct proportions, they fail to use them optimally. The literature on flexible specialization points to another aspect of managerial capability. Given the instability of markets, some claim small firm managers are more flexible or adaptable because they are unencumbered by internal bureaucracies and rigid labor contracts. On the other hand, large firm managers can draw upon greater resources with which to adapt to changing market conditions.

These arguments can be extrapolated to a dynamic context. Simply because of their numbers, small firms are motivated by greater competition and are more likely to respond to customer needs. These efforts lead to product improvements and innovations. In the case of large firms, these efforts are more likely to be stifled by non-competitive behavior and the requirements of high-volume production. Once again, however, if the focus is on resources and not motivation, large firms can bring to bear the latest-vintage capital and greater R&D expenditure. More importantly, given the inefficiency implied by the skewed firm size distribution, potential productivity gains are likely to be lower in LDCs, thereby compromising their prospects for achieving technological mastery.

Our attention to both TFP and efficiency measurement is not a new. Our contribution lies in their application at the micro level. Most analyses of efficiency measurement rely either on limited time-series of single firms (most often utilities or simple production processes) or on cross-sectional firm data. Our model examines both the changes in time as well as across firms. However, unlike sectoral TFP analyses relying on census or other panel data not specifically acquired for these purposes, our survey contains qualitative and quantitative information that enables us to implement and test various measures of efficiency and productivity. Moreover, we place our micro efficiency results in the context of Colombian macro productivity trends in order to provide as complete a picture as possible of the internal and external forces affecting technological mastery.

Following this introduction, Chapters 2 and 3 provide the theoretical framework for our empirical work by describing the models and techniques of TFP and efficiency measurement, respectively. In Chapter 4, we highlight the opportunities and limitations faced by firms in the Colombian metal-mechanical sector during the time period covered by our 1977 and 1986 surveys. The results from our application of a deterministic frontier production function to a sample of firms in the sector is the subject of Chapter 5. Finally, in Chapter 6, we offer conclusions about firm decisions to improve efficiency and technology and suggest policy implications for promoting technological mastery.

CHAPTER 2

NEOCLASSICAL MODELS OF TECHNICAL CHANGE

Most of growth theory has historically ignored technological change, stressing instead the process of capital accumulation. After an introductory overview of the historical roots of this apparent neglect, we examine models that attempt to quantify the relative contribution of technological change to output growth. The first is Solow's classic model of disembodied technical change measured as an unexplained or TFP residual. More recent models further refined TFP measures by analyzing the problems of aggregation and functional form, the measurement of capital, and disequilibrium conditions. These improvements help rid the TFP of the various measurement biases and problems.

These improvements are particularly appropriate in the LDC context. Here, as Chenery (1983, p. 854) notes, the process of development and its central feature of "structural transformation" are characterized by adjustment lags and persistent differences in factor returns--conditions that violate the assumptions of long-run equilibrium underlying Solow's TFP. As we will explain, these conditions require the analyst to somehow take into account the divergence between observed prices and the real value of resources they represent. For this purpose as well as apply improved TFP measurement techniques, analysts have turned to working with micro data at the establishment level, even if the focus of study are changes in industry structure and organization.

HISTORICAL ROOTS OF GROWTH AND TECHNOLOGY THEORIES

Capital accumulation has been seen as the engine of growth since the time of the classical economists. Its central place derives from the assumption of a positive time preference preventing consumption of all capital today without saving for consumption tomorrow and from the recognition that there is a time lag between capital formation and the increased supply of consumer goods that it makes possible (Blaug, 1985, p. 519).

Although the variables that determine capital accumulation and the mechanisms by which it affects the growth rate, level, and composition of output differ among economic schools, it plays a critical role in economic development.

For example, in the neoclassical system, capital accumulation along with macroeconomic equilibrium--the equality of desired savings to planned investment--is determined by household preferences. As Marglin (1984) notes, the exogenous forces of tastes, biology and technology drive the neoclassical model. In the Keynesian system investment demand, a highly subjective parameter dependent upon the state of confidence of business, is the driving force. Rather than investment adjusting to desired savings, savings through the mechanism of the multiplier adjust to satisfy an autonomous level of investment demand.[1] The distribution of the product is determined not by the technical conditions of production but by the priorities assumed in the competition between capitalists and workers, given their respective savings propensities. In the Marxist system, this competition turned into a class conflict is the force that propels the economic system.

Technological change, on the other hand, has enjoyed less sustained attention. Marx gives some special consideration to technology; it is not endogenous to production but works through the mechanism of capital accumulation to lend the capitalist subsystem its unbridled production capacity. After initial theorizing by Adam Smith with respect to specialization, the division of labor, and productivity, technology as a part of the production process was set aside. Instead, the focus turned to the neoclassical question of resource allocation and the intertemporal distribution of consumption. The technology issues surviving from the classicals were those of Ricardo and his examination of the impact of labor-saving technical change, thereby beginning a long tradition of the study of factor bias and the choice of technique.

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[1] Blaug (1986) and Marglin (1984) identify two other important departures from neoclassical thinking introduced by Keynes: (1) the equality of saving and investment brought about by variations in quantities i.e., output/income rather than the prices such as the rate of interest, and (2) an equilibrium level of income equating saving to investment not usually coincident with full employment.

Rooted in the problems of resource allocation, the orthodox approach defines technology as an external disturbance to the economic system. Technological progress is dependent upon the state of scientific knowledge and autonomously supplied inventions. Since John Stuart Mill's perception of the stationary state, technical change has been viewed as creating a temporary disturbance that brings the system to another equilibrium point as variables adjust, each one in proportion to the other under perfect competition. This requirement of proportional growth defies the historical record as modern industrial economies have become more capital intensive and more productive as a result of both technological progress and increasing returns to scale (Solow, 1970).[2]

In the remainder of this chapter we trace analytical efforts to model technological change and increasingly incorporate the complexities associated with it. Together with models described in Chapter 3, this literature review will show how conventional thinking about technological change has shifted from a view of such change as an exogenous shock to the economy to one endogenous to production units.

DISEMBODIED TECHNICAL PROGRESS AND THE AGGREGATE PRODUCTION FUNCTION

The importance of technology to the growth process was dramatically brought to the forefront by the sources-of-growth model, a supply-side version of the traditional demand-oriented neoclassical growth model. This model became the basis of a wealth of econometric work as it extrapolated into the macro setting the assumed behavior and relations of micro units postulated in production theory.

The classic work in this respect is Solow's (1957) attempt to account for the sources of growth in the United States economy from 1909 to 1940. He found that 90% of

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[2] The work of Teubal (1987) along with Rosenberg's historical analyses (1976, 1982) provides a useful guide for planners willing to complement neoclassical analyses with more eclectic alternative models that can account for some of the non-linearities and disproportionalities of technology.

the growth in output per capita was attributable to technical change that is assumed to be disembodied, i.e., neutral in terms of its relative impact on factors, and exogenous. The key assumptions are borrowed from growth theory. The model assumes there is a single homogeneous good used for both consumption and as perfectly malleable capital stock. This allows the production function to include a measurable capital input (a stock) measured in the same units as output (a flow).

The model is defined by the aggregate production function which includes a shift factor ($A(t)$), also known as the efficiency parameter. It measures the displacement of the constant returns to scale (CRS) production function caused by Hicks-neutral technical change

$$Q = A(t)f(K,L)$$

where Q = *output*
K = *capital stock*
L = *labor units*

The productivity or efficiency improvements modelled by the shift factor are a function of time, such that these correspond to a pure learning-by-doing effect where both labor and capital grow more productive with experience. In short, Hicks' neutral technical change is equally labor- and capital-augmenting, such that it leaves the ratio of marginal products unaffected. As shown in Appendix A, by differentiating with respect to time, equating factor shares with factor elasticities, and rearranging terms, we get the familiar equation in which the rate of growth in output is decomposed into the rate of disembodied technical change A' and the rate of growth of the factors.

$$Q' = A' + \theta_K K' + \theta_L L'$$

where the prime notation denotes rate of growth , i.e., $A' = (dA/dt)/A$
$\theta_X = \partial Q/\partial X(X/Q)$ = *output elasticity of factor* $X = K,L$

The A' captures the shift in the production function, while the remaining terms capture movements along the production function with the θ_X's as weights for the aggregation of inputs. This expression highlights the fact that TFP change is a residual after accounting for the growth in output due to changes in the quantity of factor inputs as well as for cost minimizing use of input combinations over time in response to shifts in factor prices. Solving for A', this expression also yields the familiar formula for the Divisia index of TFP change, discussed in the next section.

Applying Euler's theorem, given that CRS assumes *f* is linear and homogeneous, if factors are paid their marginal products, their shares in Q exhaust the product ($\theta_K = 1 - \theta_L$). Rearranging in per capita terms

$$q' = A' + \theta_K\, k'$$

$$\text{where } q' = Q' - L' \text{ and } k' = K' - L'$$

or in discrete approximation

$$\Delta q/q = \Delta A/A + \theta_K\, \Delta k/k$$

Solow uses this equation to estimate the relative contributions of capital-deepening (k') and the shift factor (A'), using annual series of real private non-farm GNP per person-hour, the capital share (a composite of assumptions), and capital stock per head (excluding government, agricultural, and consumer durables and adjusted for capacity utilization by the percent of labor unemployed). Given the key assumption of neutrality, and beginning with an initial level of A, Solow treats the data points described by his model as belonging to an underlying production function shifting upwards (Harcourt, 1972, p. 50).[3] After plotting the estimated A against the capital-labor ratio, Solow concludes neutrality on average since there is no apparent relationship. Similarly "presumptive evidence of neutrality" derived from empirical findings in the 1940s suggesting the long-run stability of

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[3] To capture the changes in production relations over time captured by A, it is introduced into the production function as a variable with an initial level of A^*:

$$\log Q_t = \log A^* + \log A_t + \beta \log K_t + \gamma \log L_t + u_t$$

However, since we assume a proportional (neutral) shift in the production function we can set $\log A_t = 1$ and then fit

$$(\log Q_t - \log A_t) = \log A^* + \beta \log K_t + \gamma \log L_t + u_t$$

the aggregate capital-labor ratio had led to the widespread assumption of neutrality (Blaug, 1985, p. 479). This assumption glosses over the fact that only strongly biased technical progress is picked up by the aggregate capital-labor ratio. The latter also reflects the influences of savings, investment allocation across industries, expectations about future technical change, and past patterns of growth in output.[4]

Notwithstanding the lack of consensus on how to measure neutrality and the weakness of the evidence cited, it is equally difficult to accept the notion of a persistent bias in innovation toward capital-saving or labor-saving technology. A persistent bias in innovations would be corrected by the market mechanism. Furthermore, considering the theory of the competitive firm, the goal is to reduce total costs not those associated with a particular factor. This discussion points out that it is by no means simple to distinguish, either in theoretical or empirical terms, the effects of bias and technical change as movements along and shifts of the production function.

The ingenious simplicity of Solow's work belies the theoretical and measurement problems associated with Solow's production function models. Reviewing the model, Nadiri (1970, pp. 1141-1143) emphasized that the shift factor is dependent upon: (a) the functional form of the production function determining the marginal products, (b) the appropriate measurement of factors, and (c) the impact of omitted variables. With respect to the form of the production function, Brown (1966, p. 104) and Solow (1970, p. 34) consider the assumption of constant returns to scale as the most restrictive. The problems of measurement involve proper aggregation to distinguish those commodity differences related to productivity differences. The issue of incomplete specification of the function relates to omission of a third factor, such as land or public goods, or variables, such as

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[4] Later, Solow noted that the capital-labor ratio can change in a way that, despite no evidence of proportional changes in the function, there may still be non-neutral technical change (Brown, 1966, p. 104).

entrepreneurial ability. These problems are further complicated by the interdependence between the technical characteristics of production and the movement of relative prices.

The technical characteristics refer to efficiency, bias, elasticity, scale, and homotheticity. The first three are related to shifts in the unit isoquant; technical change can increase efficiency by reducing the unit costs of all factors (parallel shifts towards the origin) or biasing them towards one factor (non-parallel shifts towards one axis), or can affect the substitutability between factors (changes in curvature). The scale effects reflect the efficiency increases from different levels of output, while homotheticity would reflect the bias associated with scale changes. For example, in the case of a nonhomothetic production technology, the substitutability between factors is a function of output scale such that isoquants for different output levels may intersect.

These technical characteristics are interdependent and not easily distinguishable from the effects on productivity of movements in relative prices. If there is scope for substitution (i.e., elasticity of substitution > 0), such movements will impact on factor productivity as factor proportions adjust to new factor prices. In principle, the price effects can be disentangled from changes in scale and factor proportions using both quantity and price input/output data at the micro level. In practice, the measurement and estimation problems can be overwhelming even when relying on the so-called flexible production functions to examine the validity of our restrictions upon the production technology. Moreover, even after having disentangled price effects from technical characteristics of production, the possibility of errors in optimization remains as a further source of bias to TFP estimates.

In addition to these empirical problems, the changes over time and across productive units of the technical characteristics of production may pose serious problems for the integrity of the production function. Particularly in the aggregate, these problems may undermine the stability of the economy-wide production function as a basis for long-run growth theory. Brown (1966, p. 105) charged that at this level of aggregation, Solow confused changes in the composition of output with changes in the production function he intended to measure. It is no wonder that later work abandoned the economy-wide production function in favor of sectoral disaggregation, pioneered by Salter (1966, originally published in 1960) in his seminal work on technical change in individual industries (see Appendix A). However, even sector-level TFP results require careful interpretation. Reviewing TFP analyses based on sectorally aggregated data, Tybout (1989) charged that these TFP estimates confounded the various technical characteristics of production. Indeed, recent studies such as Tybout , Corbo and de Melo (1988), Roberts (1988) and Caves and Barton (1990) have used plant-level census data to study productivity changes. At the micro level, the TFP measurement improvements we describe below are far easier to implement.

TFP IMPROVEMENTS

This section outlines three important refinements that analysts have made to the measurement of total factor productivity. The first focuses on the application of index number theory to problems of aggregation. The index number approach is an extension of growth accounting in which the production function is used as an accounting format rather than an estimation framework as seen in Solow's TFP model above. The choice of an index number formula implies a given production or aggregator function; therefore, the choice of functional form, in turn, implies an appropriate index number (Caves, Christensen, and Diewert, 1982).

The second involves improvements in the measurement of capital by explicitly accounting for its vintage so that capital of differing vintages may reflect differing productivities. The third refinement deals with the adjustment for capacity utilization. Analysts such as Nishimizu and Page (1987) imply that fluctuations in capacity utilization are short to medium-term phenomena, which need not contaminate long-run TFP measures. Nevertheless, we find a growing literature purporting adjustments in order to isolate the symptom of capital underutilization from other forces acting on TFP.

Index Numbers: Aggregation and Functional Form

Aggregation at any level is premised on the perfect substitutability of units within the aggregate. Given a competitive market and perfect foresight, aggregation across different types of units is accomplished by weighting quantities with relative factor rewards reflecting relative marginal productivities. This weighting is a shortcut for fulfilling the requirement of perfect substitution between different units in the aggregate--the organizing principle of index numbers. In this section, we focus on the seminal work of Jorgenson and Griliches (1967) whose attempts to pare down the TFP residual using index numbers and the production function as an accounting framework set the standard for a wealth of current productivity studies. These studies represent a departure from Solow's econometric estimation of the aggregate production function; they are basically accounting exercises at the sectoral level. Disaggregation is their key feature in an attempt to account for structural change which is at the heart of the development process.

Jorgenson and Griliches (1967) carried quality-correction to an extreme by attempting to explain away the TFP residual, contending its existence reflected the incorrect measurement of input services in the aggregate production function. Their view of TFP brings into sharper focus the nature of disembodied neutral technical change as learning-by-doing. The TFP, the authors note, captures the effects of "costless advances in applied technology, managerial efficiency, and industrial organization" (Jorgenson and Griliches, 1967, p. 250). When changes in applied technology involve the use of scarce resources, then their alternative deployment involves movements along the production function. Given the limited scope for truly costless advances, the TFP should be correspondingly low.

Beginning with the basic national accounting identity, they estimated the TFP rate of growth as the difference between the rates of growth of real product and real factor input utilizing Divisia quantity indexes.[5] These rates are defined as weighted averages of the rates of growth of individual products (factors) where the weights are the relative shares of each product (factor) in the value of total output (input). The TFP rate of growth may be expressed in terms of the quantities of the *j*th output (q_j) and *i*th input (x_i) and their corresponding prices (p_j and w_i)

$$TFP' = Q' - X' = \Sigma r_j q_j' - \Sigma s_i x_i'$$

where the prime notation denotes rate of growth , i.e., X' = (dX/dt)/X

and r_j is the revenue share of the *j*th output defined as

$$r_j = \frac{p_j q_j}{\Sigma_m^j p_j q_j} \qquad j = 1,\ldots,m$$

and s_i is the cost share of the *i*th input

$$s_i = \frac{w_i x_i}{\Sigma_n^i w_i x_i} \qquad i = 1,\ldots,n$$

As in Solow's (1957) parametric approach, the use of prices as weights for aggregation in Divisia indices assumes revenue (cost) shares are equal to cost (output) elasticities reflecting their marginal productivity. In other words, assuming CRS and marginal rates of substitution equal to corresponding price ratios, Jorgenson and Griliches showed that a TFP Divisia index greater than zero will denote a shift in the production function, while movements along it are captured by the input indices.

The application of Divisia index formula is facilitated by its discrete form log change Törnqvist approximation to the continuous time formula cited above

$$TFP\ \Delta = \log(q_t/q_{t-1}) - \log(x_t/x_{t-1})$$

$$\text{where } \log(q_t/q_{t-1}) = 1/2\ \Sigma_m^j (r_{jt} + r_{j,t-1}) \log(q_{jt}/q_{j,t-1})$$

$$\log(x_t/x_{t-1}) = 1/2\ \Sigma_n^i (s_{it} + s_{i,t-1}) \log(x_{it}/x_{i,t-1})$$

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[5] The TFP index can also be computed using the dual expression relating the rates of growth of prices i.e., TFP'= w'- p' (Jorgenson and Griliches, 1967, p. 251-252) rather than that of quantities.

When the conditions of CRS and perfect competition in markets for inputs and outputs do not hold, the index number approach may not be appropriate. As we noted in reviewing Solow's TFP, the residual may pick up the influences of increasing returns to scale, errors in optimization, and non-competitive markets. If quantity and price data are available, analysts can use econometric approaches to test for these conditions and decompose the residual to identify the sources of productivity change. In the more usual case where such data are not available, analysts proceed with the TFP calculation and sometimes introduce second-best adjustments to estimate the potential source and magnitude of the biases on TFP indices.

However, even when data are scarce, analysts are increasingly turning to index numbers based on more flexible aggregator functions. As defined by Caves, Christensen and Diewert (1982), these functional forms represent an arbitrary set of revenue and cost shares and corresponding elasticities at a specified base point. They accommodate a variety of substitution possibilities, including the unitary elasticity of the Cobb-Douglas case and the constant elasticity of the CES (constant-elasticity-of-substitution) form. This flexibility is particularly important when we are trying to sort out returns to scale. Page's (1984) work described in Chapter 3 provides an example of the application and advantages of the transcendental logarithmic or translog index number, which corresponds to the translog production function, a flexible form in which output is an exponential function of the logarithm of inputs.

The application of index number formulae to the measurement of flows of output and labor services is based upon data on the value of transactions of each type of output and service, which are separated into price and quantity components. Usually this is done using price indices since quantity data are seldom available for all the series required. Divisia quantity indexes are then calculated as shown in the formula above.

In the case of labor, following Denison's (1962, 1974) well-known efforts, labor-hours are aggregated using relative wages as weights, in effect, producing a measure of labor in efficiency (or quality-corrected) units. The use of earnings is subject to the usual weaknesses in terms of the sensitivity of the results to the classification of groups and the presence of externalities causing divergence between earnings and productivity. For these reasons, Denison developed a quality-corrected series of labor-hours that takes account of educational quality, sex-age composition, number of hours worked, and disequilibrium or structural factors such as sectoral labor shifts. Denison focused on labor because it is labor's knowledge accumulated through education and experience that incorporates technical change into capital goods. Moreover, contending that the age distribution of the gross capital stock had not nor is likely to vary (a contention examined and rejected by Kendrick), Denison discounted capital-embodied technical change in his sources-of-growth calculations.

As we noted, current practice in productivity studies does not attempt to account for disequilibrium factors. The assumption is that these are minor effects in industrialized economies. Even in the context of developing countries where the development process is characterized by adjustment lags and persistent differences in factor returns--conditions that violate the long-run equilibrium assumptions underlying TFP--data are seldom available to compare TFP at market and at shadow prices. The work done by Roberts (1989) on Colombia and described later in Chapter 5 is a case in point. Once estimated, the TFP indices and variables picking up sources of disequilibria , such as industry concentration for the existence of market power or noncompetitive behavior, demand fluctuations to capture capacity utilization, are examined with multiple correlation techniques.

Unlike Denison, Jorgenson and Griliches (1967) focused their efforts on the measurement of capital to which we now turn.

The Rental Price of Capital

As Jorgenson and Griliches (1967, p. 255) noted, the calculation of capital services involves a "lengthy chain of indirect inference." It begins with data on the components of the capital stock and value of transactions on new investment goods. Unfortunately, these transactions prices are not an adequate valuation of capital services. Capital assets are usually owned and used by the same group and well-defined rental markets for components of the capital stock seldom exist (Diewert, 1979; Mohr, 1988). To solve this lack of directly observable capital input prices, Jorgenson developed his neoclassical model of the rental price of capital based on the firm's optimizing behavior. Beginning with the constrained optimization problem to show that the rental price of capital is equal to the marginal value product per unit of capital services, that is, $p_K(t) = p_Q(t)\, \partial F / \partial K$, Jorgenson's dynamic optimization analogue yields the flow or rental price of the Kth capital service:

$$p_K(t) = q(t)\,(r + \delta - q')$$

where q = *investment price of the capital good (asset price)*
r = *rate of return on all capital*
δ = *rate of depreciation*
q' = *rate of capital gain*

Capital stock estimates are then used to derive a Divisia quantity index of total capital input using the implicit rental value of services as weights. Usually, the capital stock is estimated with the perpetual inventory method in which an initial estimate of the capital stock is increased by annual estimates of net investments.

The most problematic component in the formula is the rate of return on capital. In their application, Jorgenson and Griliches estimated the rate of return on all capital (r) by dividing the non-wage share of value added (including capital gains) by the current value of the capital stock. As Mohr (1988) pointed out, this implies that entrepreneurs make capital investment decisions (i.e., whether to add to, replace, or liquidate portions or the entirety of their capital stock) on the basis of the historical rather than current or replacement cost of funds. This may overemphasize historical performance by underestimating the opportunity costs of continued investment in that industry. Using the example of the U.S. Steel industry, Mohr (1988, p. 114) demonstrated that in the case of declining industries the market is probably charging them "a premium that reflects the increased bankruptcy and price risks associated with continued investment in them."

To avoid the problem of historical versus current costs, Mohr proposed a vintage rental price of capital formulation to reflect the composite historical costs of the mix of vintages in the existing stock.

$$p_{vt} = q_{vt} (r_{vt} + \delta_t - q_{vt}')$$

where v= vintage or age and t = type of asset

In Mohr's vintage model gross investment is valued at the current cost of funds and net capital at the historical cost corresponding to respective vintages. This complicates matters greatly since Mohr argued that the aggregate rental price of capital should be calculated from components that are weighted averages. This means we calculate, in effect, a linear aggregation of the constant dollar perpetual inventory flows over all vintages and capital types. The implementation of Mohr's formulation is only recently becoming possible at the macro level with the construction of specialized data sets (e.g., Jorgenson and Fraumeni (1986) sectoral vintage accounts for capital). In the Technical Appendix we explain how we applied Mohr's vintage rental price of capital formula to our firm-level sample.

Returning to Jorgenson and Griliches' (1967) efforts to pare down the TFP residual, they found that their measurement improvements lowered their pre-correction TFP estimate of 1.6% to an average annual rate of 0.3%. In addition to the rental price of capital calculations, the main improvements included use of Divisia indexes and closer attention to the choice of commodity groups in aggregation. Many of the problems with quality correction, they maintain, can be solved by greater disaggregation and use of hedonic indices which utilize evidence on differences in marginal productivities across groups. In subsequent work, Jorgenson applied his first suggestion together with the estimation of a quality constant--a function of time and the composition of the capital input. As capital services with relatively high prices become more important in the total flow of capital services, sectoral capital quality increases (Jorgenson and Fraumeni, 1986).

Another refinement in their measurement of inputs involved the capacity-utilization adjustment. Just as Denison introduced the adjustment for hours worked for labor, Jorgenson and Griliches (1967) adjusted their capital stock estimates with data on the relative utilization of energy to account for the fluctuations in capacity utilization. These authors use the average kilowatt hours of motors as the weight used to combine the utilization rates across industries to obtain the total manufacturing utilization series. This adjustment necessarily misses the short-run cyclical fluctuation in capacity utilization and assumes uniform relative utilization within industries. Below we explain why an adjustment for capacity utilization is needed.

Adjusting for Capacity Utilization

The adjustment for capacity utilization is a recognition that TFP measures assume markets for inputs and outputs are in long-run equilibrium despite the reality that a firm's capital stock may adjust slowly to changes in relative prices. Without this adjustment, Hulten (1986) explained, true TFP growth (A') is contaminated by our erroneous key assumption that capital services are proportional to capital stocks

$$A' = Q' - \theta_K [U'_K + K'] - \theta_L L'$$

$$\text{and } A'' = A' + \theta_K U'_K$$

where θ_X = factor share or output elasticity
$U_K = J/K$ = service flow/capital stock = capital utilization ratio
A'' = unadjusted TFP rate

If we could observe the θ_X and the capital and labor service flows, the original TFP formulation (without U'_K) would yield the true A' regardless of temporary disequilibrium. Without such information we face the prospect that our weighting scheme may no longer be appropriate, if the condition of full capacity utilization underlying the proportionality assumption is not fulfilled because certain inputs are quasi-fixed.

Hulten further shows that in the presence of this mismeasurement (of the weights in the capital input), the dichotomy between shifts in and movements along the production function is seriously confounded. For example, a reduction in capital utilization (with constant capital stock, labor, and technology) will be picked up as a fall in TFP rather than a decrease in the quantity of capital services utilized. Most alternatives, following Jorgenson and Griliches above, involve quantity adjustments. However, despite its limited application, the Berndt and Fuss (1986) method focusing on price adjustment is becoming the preferred method for accounting for the variation in U'_K. [6]

Price adjustments involve estimating short-run cost curves to derive the shadow price of capital. In long-run equilibrium the capital-utilization ratio is equal to unity, but when $U_K(t) \neq 1$ the factor price is no longer equal to the shadow or long-run rental price of capital w_K

$$p_Q(t)\ \partial Q(t)/\partial K(t) = Z_K(t) \neq w_K(t)$$

$$\text{where } Z_K(t) = \text{quasi-rent earned by capital}$$

As Berndt and Fuss (1986) explained, $Z_K(t)$ can be considered the additional expected profits during period t from adding one more unit of capital. When $Z_K(t) = w_K(t)$, the firm has no incentive to change its stock of capital , i.e., its location on the short-run average cost curve coincides with the long-run cost-minimizing point. However, when $Z_K(t) < w_K(t)$, the firm encounters a relative surplus and has the incentive to disinvest. It can maintain its output level while decreasing long-run average total costs.

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[6] The work of Berndt and Fuss, Hulten, and others is compiled in the Special Issue on the Econometrics of Temporary Equilibrium in the *Journal of Econometrics* 33(1986).

The empirical problem lies in estimating $Z_K(t)$. Ideally, $Z_K(t)$, interpreted as the expected shadow rental price of capital, can be approximated with Tobin's q and Jorgenson's rental price of capital formula--$Z_K(t) = q(t) \cdot p_K(t)$. Tobin's q incorporates information about investor expectations implicit in the stock market valuation prices. Berndt and Fuss (1986) compared traditional TFP estimates (using Jorgenson's rental price of capital) with those derived from their adjusted model using Tobin's q to correct the rental price. Their calculations using U.S. data (1948-1981 broken down into subperiods) show that the TFP growth slowdown in U.S industry is significantly less than traditionally measured. Between the periods 1965-1973 and 1973-1981, the utilization adjusted TFP is about 65% larger than the traditional measure. Thus, rather than looking for structural failures, these findings show that a major problem in productivity trends were those related to the cyclical reductions in capacity utilization.

In the case of LDCs, an approximation of Tobin's q is practically impossible because of their generally shallow capital markets. We are left with the recognition of an important potential bias in our TFP estimates and a second-best adjustment for capacity underutilization focusing on quantity rather than price. Even this second-best adjustment is preferable to confusing structural declines in productivity with cyclical or temporary reductions.

CONCLUSIONS

Our review of neoclassical models of technical change brought out a set of guidelines for measurement, which will be echoed throughout the next chapter. First and foremost, we must verify our assumptions about the underlying production technology and choose index number formulae that correspond to these assumptions. Second, in the case of measuring capital and labor inputs, we must incorporate skill and vintage differentials that are likely to have an impact upon productivity measurement. Third, even if we are limited to second-best adjustments in capacity utilization, it is important to estimate the magnitude of the potential bias. This is also true in the case of other types of disequilibria, such as price distortions, which are particularly important in developing countries given the popularity of import substitution policies. These guidelines can help in reducing the biases to the TFP residual from non-constant returns to scale and the effects of temporary disequilibrium where the prices used as weights in aggregation do not accurately reflect relative marginal productivities.

As we noted in the critique of Solow's TFP, given the empirical problems in correctly specifying the technical characteristics of production, let alone their changes over time, analysts have increasingly turned to flexible functional forms and disaggregated analyses based on micro-level data. These data allow us to deal with another source of TFP bias--errors in optimization. This is the subject of the next chapter.

CHAPTER 3

DEPARTURES FROM THE NEOCLASSICAL MODEL

The large literature on efficiency measurement in production reflects the belief of many analysts that errors in optimization are an important source of bias in measuring productivity performance. Traditionally, this literature has focused on cross-sectional comparisons. However, with the work by Nishimizu and Page (1982) described below, the analytical tools to measure the inefficiency introduced by errors in optimization in a static context were integrated into the TFP's dynamic context. If errors in optimization reduced the efficiency of firms in a given time period, these inefficiencies would have to be taken into account in determining their net productivity gains across time periods. As Lovell and Schmidt (1988, p. 4) note, "it [the TFP decomposition by Nishimizu and Page] enables one to enrich Solow's dichotomy by attributing observed output growth to movements along a path on or beneath the production surface (input growth), movement toward or away from the production surface (efficiency growth), and shifts in the production surface (technical change)."

The key analytical construct of this literature is the frontier production function which sets the standard for measuring a unit's relative efficiency. After an explanation of the premises and methods of efficiency measurement, the second part of this chapter reviews the empirical work focusing on the hypotheses to be tested as analysts attempt to uncover why certain firms are more efficient and whether efficiency is related to technical change.

EFFICIENCY OF PRODUCTION AND ITS MEASUREMENT

Implicit in the concept of the production function is the notion of maximization. This suggests producers are efficient--optimizing subject to the binding constraint imposed by a freely accessible technology; however, when we try to estimate the production function, we observe both efficient and inefficient producers. In response to these realities, the literature on efficiency measurement has developed the concept of the frontier production function to distinguish between these types of producers (Färe, Grosskopf, and Lovell, 1985, pp. 9-15). A contrasting view is explained by Seale (1985) in which differences across units are attributed to differing levels of fixed factors rather than to inefficiency. However, he notes, whether one views the differences as a result of managerial capabilities or differing levels in the relatively fixed factor of managerial know-how is a semantic, not a substantive, difference.

The frontier defines the best-practice rather than average technology thereby approximating the theoretical meaning of the production function. The frontier sets the standard for comparing the efficiency of production units utilizing similar technology. Efficient units define the frontier and the distance from the frontier provides a measure of an interior unit's inefficiency. From efficiency rankings, analysts attempt to identify the causes of these errors in optimization in order to guide policy action to mitigate them. For example, are the main causes of these errors the manager's inadequate technical or administrative training or does the problem lie with the prices he/she faces in the market that distort the use of inputs. In the former labelled technical inefficiency, programs for training and information dissemination may be appropriate while in the latter labelled allocative inefficiency, removing government intervention in credit and input markets may be warranted. The typology of inefficiency is important if we are trying to evaluate the performance of firms and to diagnose and formulate remedies for their failures. Different policies may be needed to impact upon the larger production environment faced by the firm and/or the micro environment within its plant.

According to Farrell (1957) these two types of inefficiency, technical and allocative, must be distinguished analytically. The first relates to suboptimal usage of inputs or the failure to maximize output with given inputs. The second relates to distorted input proportions or the failure of producers to utilize the cost-minimizing input mix. A technically efficient combination of inputs places the firm on the production surface. However, in order for this technically efficient combination to qualify as the least-cost combination, it must coincide with the point of tangency between the production surface and the factor price line. Neoclassical theories of production eliminate the possibility of technical inefficiency, because they assume producers optimize subject only to the binding constraint represented by freely accessible technology. Moreover, the first-order conditions relating marginal products to factor prices effectively eliminate the possibility of allocative inefficiency.

Another important type of inefficiency, scale inefficiency, relates the size of producing units with the minimum efficient scale. Unlike technical efficiency, scale inefficiency is not under the direct control of the firm, but reflects industry structure and the scale of operations it allows. The measurement of scale efficiency has been a key issue in investigations of the effects of inward-oriented development strategies upon domestic markets. For example, Tybout, Corbo, and de Melo (1988) estimated conventional production functions for 18 Chilean industries using plant-level data to examine industry-wide scale and technical efficiency before and after import liberalization. These authors used the standard tests for scale economies (the sum of input coefficients) and estimated average technical efficiency and the dispersion about this average with the intercept and variance from conventional production function estimation (although based on full-information, maximum-likelihood estimators). They found evidence of positive effects on both types of efficiency from import competition.

These authors were interested in industry-wide patterns of average technical efficiency. They were not interested in firm-specific efficiency rankings or inter-industry efficiency comparisons where the requirements of conventional production function estimation are lacking and frontier models are more appropriate. The work of Caves and Barton (1990), for example, focuses on inter-industry efficiency comparisons and uses frontier methods to compare efficiency levels across industries with different production functions. After an explanation and comparison of the techniques of efficiency measurement, we describe empirical applications of frontier models to derive firm-specific efficiency rankings.

Steps in Efficiency Measurement

Färe, Grosskopf, and Lovell (1985) specified a three-step procedure in efficiency measurement. The first step is to determine the behavioral objective of the firm. This is important, if we are interested in allocative efficiency rather than only technical efficiency. If we have complete price and quantity data available, then we can examine allocative efficiency after choosing the appropriate dual function, i.e., cost, revenue, or profit function, establishing the choice variables for the producing unit using direct estimation techniques. For example, if we are dealing with a firm in a regulated industry, direct estimation of the cost function would yield information on the extra costs of technical and allocative inefficiency. The choice of the cost function reflects our assumptions that the input level is the choice variable and the production unit takes the level of output as given, as in the case of cost minimization. As explained by Forsund, Lovell, and Schmidt (1980, p.7), the firm faces the classic constrained-optimization problem:

$$C(y,w) \equiv \min w \cdot x \qquad s.t.\ f(x) = y$$

where $C(y,w)$ *is the cost function in which output level and input prices are exogenous*

y = *output vector*

w = *input price vector*

x = *input vector*

whose first-order conditions establish the equality between the ratio of input prices and the technical rate of substitution, holding the level of output constant. The first-order conditions (FOC) are given by

$$wi/wj = \frac{\partial f(x^*)/\partial x_i}{\partial f(x^*)/\partial x_j} \qquad \text{the technical rate of substitution}$$

where x^* *denotes the optimal* x

This defines the point of minimum costs as the tangency between the isocost line [for i = 1,2, $C = w_1x_1 + w_2x_2$] and the isoquant. If this equality does not hold, the firm is allocatively inefficient, employing inputs in the wrong proportions, i.e., $w{\cdot}x > C(y,w)$. If the firm fails to choose the maximum output level, $y < f(x)$, it is also technically inefficient. Only if the firm is both technically and allocatively efficient will observed expenditure coincide with minimum cost, $w{\cdot}x = C(y,w)$. Moreover, if the firm's output price does not follow the marginal pricing rule, $p_y \neq C(y,w)$, the firm is scale inefficient. Only if the firm is technically, allocatively and scale efficient will it meet the conditions for profit maximization, i.e., $(p_y\, y - w{\cdot}x) = \pi(p_y,w)$.

Complete price and quantity data are seldom available to examine all three types of inefficiency. In these rare cases, the analyst can use estimation of dual cost or profit functions to derive estimates of allocative efficiency. Most frontier applications have focused on production frontiers, which yield information on technical efficiency alone. Direct estimation of the production frontier is based on the behavioral assumption attributed to Zellner-Kmenta-Drèze that firms maximize expected profits. This assumption implies that output is endogenous; entrepreneurs can sell any amount of output they produce without affecting the market. Output as well as input prices are given so that the optimization problem for the entrepreneur is to produce the output level which maximizes expected profits. Similarly, in non-frontier or conventional estimation, this assumption allows us to derive unbiased estimates of the production parameters from ordinary least squares (OLS).

The second step in efficiency measurement involves specifying the technology or flexibility of the functional form of the frontier. This selection then guides the third step of choosing the computational method. If little is known about the structure of production, the non-parametric linear programming method imposes the least structure. With this method (also referred to as data envelopment analysis), Lovell and Schmidt (1988, p. 13) explain, no parameters are computed, "the sample data are bounded or 'enveloped' by a convex hull" of the observed input-output ratios. For example, Farrell's unit isoquant is a series of connected hyperplanes convex to the origin in input space (Kopp, 1981). Despite its flexibility and ability to derive unit-specific indices of technical inefficiency, this pure programming method has three main disadvantages. First, all variation in output is attributed to differences in technical efficiency, thereby ignoring random noise. Second, there are no statistical tests for goodness of fit from which to make inferences. Third, Farrell's unit isoquant requires the assumption of CRS.

On the other hand, parametric programming and statistical methods utilizing the Cobb-Douglas impose either, greater or, in the case of the translog, fewer restrictions on the structure of production. The deterministic parametric frontier allows non-CRS technologies, but is subject to the same drawback as the pure programming approach. In addition, it is sensitive to outlier or extreme observations. This has prompted efforts to "desensitize" the frontier by reestimating its parameters excluding a percentage of the most efficient firms until the parameters stabilize.

In order to incorporate random error into frontier models, analysts include random and nonrandom components in composed error models where the nonrandom component represents technical inefficiency. The advantages of this statistical model come at a price. The analyst must assume a particular distribution for the error term, but there are no a priori arguments from which to base this selection, and results are sensitive to these distributional assumptions. Perhaps more importantly from a practical perspective, stochastic frontiers in a cross-sectional context yield only average sample-wide measures of technical inefficiency. This has limited their application in policy-oriented studies.[1]

Rather than focus on the error term distribution within a flexible functional form, Tybout, Corbo, and de Melo (1988) suggest that the more pressing problems lie with the explanatory variables. Particularly for LDCs, capital-input data are often missing or biased

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1 Recently, a methodology to decompose individual efficiency indices has been proposed and is not yet widely practised, particularly since resulting estimates are inconsistent.

by inflation and underreporting. Accordingly, they set aside the issues of how to compensate for nonnormal errors. Errors in variables not only make standard production parameter estimators inconsistent, but also distort the residual term upon which the analysis of technical efficiency is based. Missing data reduce the power of standard estimators. To respond to these problems, the authors develop full-information maximum likelihood estimators of production technologies, assuming a Cobb-Douglas technology using the instrumental-variables approach. As noted, Tybout and his co-authors are not interested in unit specific efficiency measures, but rather in sectoral averages and how these are related to measures of protectionism and industrial structure. Given their level of analysis, they can bypass the issue of manipulating the nonnormal error to derive measures of firm technical efficiency.

Comparison of Frontier Methodologies

Lovell and Schmidt (1988) and Schmidt (1985) compared frontier methodologies and provided a summary of their relative advantages and disadvantages. Although stochastic methods allow us to differentiate between technical efficiency and statistical noise, the complexity and sample size requirements of this method have proved an obstacle to some empirical work. Most empirical work has focused on technical efficiency (rather than allocative efficiency), reflecting the usual lack of price and quantity data and has relied on the deterministic programming frontier given its computational simplicity. However, in recognition of the statistical noise confounding their technical efficiency measures, these analyses usually follow the estimation of technical efficiency indices (TEIs) with an examination using multiple correlation techniques of variables explaining their variation. These variables attempt to compensate for omitted (i.e., entrepreneurial abilities) or ill-measured inputs (i.e., plant vintage compensates for the failure of asset prices to reflect capital productivity). They include the experience of the entrepreneur, the labor force, and the firm, the vintage of capital equipment, and the extent of seasonal output fluctuations.

Schmidt (1985), a proponent of stochastic methods, considers such efforts to "explain" the technical efficiency measure a poor substitute for the proper and complete specification of the initial model. Although we agree that such efforts may be poor substitutes, we find studies focusing solely on the methodological issues equally lacking from a policy perspective. Most analysts interested in efficiency and productivity admit to the complexity in modelling these phenomena. No single technique is clearly superior or applicable in all circumstances and, in most cases, the analyst must bring to bear a wealth of corroborating data to supplement and support the result of whichever model is chosen. Below we describe how different authors have used the methods of efficiency measurement to examine firm performance.

EMPIRICAL APPLICATIONS OF EFFICIENCY MEASUREMENT

In this section we describe the work of Cortes, Berry, and Ishaq (henceforth CBI, 1987), Page (1984), Nishimizu and Page (1984) and Cornwell, Schmidt, and Sickles (1988). The first two sets of authors applied deterministic programming frontiers in a cross-sectional context, and together with analysts such as Meller (1976) and Little, Mazumdar, and Page (1987), they focused on the relationship between size and technical efficiency. In effect, they examined issues related to scale efficiency by studying the pattern of technical efficiency across size groupings for evidence of minimum efficient scale, capital indivisibilities, and scale economies. Nishimizu and Page (1984) and Cornwell, Schmidt, and Sickles (1988) examined the sources of productivity change over time, using frontier methods applied to panel data. In the static context, analysts seek to identify the determinants of technical efficiency. In the dynamic context of productivity changes in time, they attempt to relate technical efficiency at a given period with technical change over several periods.

None of these analysts attempted direct measurement of allocative efficiency--the optimality of the input mix given relative input prices--given limited data availability. However, each made an attempt to examine indirectly differences in factor proportions and relative prices as related to technical efficiency. This reflects a recognition that the issue of relative prices, whether they reflect relative scarcities or are biased by disequilibrium conditions, is particularly important in developing countries, following the import-substitution development model. Page(1980) in his study of Ghanaian lumber-related industries is one of few analysts to measure allocative efficiency directly. Using accounting or shadow prices, Page compares the percentage reduction in domestic resource costs from technical and allocative efficiency improvements. For the industries studied, which included unprotected and protected industries, Page found larger reductions in these costs from technical efficiency gains. This result suggests that most analysts, by focusing on technical efficiency, are devoting their attention to the most important source of inefficiency.

The studies described below illustrate methodological developments as analysts seek to introduce the random error component to examine patterns of efficiency and productivity over time as well as across firms. In choosing the appropriate methodology, analysts must trade off model features. The more theoretically appealing models make considerable demands upon data and estimation techniques; they tend to limit the analyst to simple production processes, characterized by homogeneous inputs and outputs, processes seldom at the core of manufacturing performance.

Size and Technical Efficiency

Responding to their large numbers, the attention of policy makers, multilateral aid agencies, and analysts has shifted to small-scale and micro-enterprises during the past two decades. This attention reflects this groups' surprising resilience, despite government policies affecting the trade regime, private-sector investment incentives, public-sector purchases, as well as the tax and regulatory framework, which to some degree discriminate against small-scale enterprises. This resilience is attributed to this groups' greater labor intensity. In labor-abundant capital-scarce economies, small-scale firms seem to be the prime employment generators for the unskilled, thereby contributing to reducing poverty and inequality. As Little, Mazumdar, and Page (1987) argue, if we could establish that small-scale enterprises employ capital and labor more efficiently than large firms, then output would rise and be distributed more equally if we removed the biases in government policies against these firms. Removal of such biases has become a recurrent theme in policy circles as shown by the popularity of Hernando de Soto's study of Peru's small-scale enterprises, The Other Path (1986). He, however, does not provide evidence on the greater efficiency in factor use, information which only detailed studies of firm efficiency, such as those described below, can provide.

An appropriate point of departure for our review of studies on size and technical efficiency is the work of Cortes, Berry, and Ishaq (CBI;1985). Their 1977 data on Colombian metalworking firms provides the base-year data for our empirical work described later in Chapter 5. Their examination of firm performance was prompted by the observation that small- and medium-scale enterprises (SMEs) showed greater dynamism than large-scale firms during the 1970s in Colombia. Taking advantage of the downward pressure on wages and high levels of aggregate demand, SMEs (defined as those with less than 100 employees) registered high rates of growth in employment of 8% to 9% compared to 6% by larger firms. CBI seek to explain the reasons underlying the SMEs economic performance, using a sample of 65 firms in the metalworking sector and 36 firms in food processing.

CBI found no systematic relation between size and technical efficiency. Nevertheless, in the case of metalworking, the authors concluded that the larger SMEs (from 49-99 employees) operate at higher levels of technical efficiency than smaller firms, due to the indivisibilities of capital and the tendency of the most efficient to grow faster.

Firms with 10 or fewer workers produced at 38% of best practice output compared to 70% for the larger SMEs. In this sector, capital requirements are substantial. Even for firms producing relatively unsophisticated fabricated metal products such as kitchen equipment, a variety of cutting, folding, and welding equipment is needed.

To measure SME technical efficiency, CBI calculated firm-specific technical efficiency indices (TEIs) based on a deterministic programming Cobb-Douglas frontier. The linear programming problem is to minimize the sum of deviations from the frontier across *s* firms

$$min \sum u^s$$

subject to

$$\alpha_0 + \alpha_L \ ln \ L^s + \alpha_K \ ln \ K^s \geq ln \ VA^s \ \ or \ u^s \leq 0 \qquad (s \ constraints)$$

$$\alpha_0, \ \alpha_L, \ \alpha_K \geq 0$$

in which these deviations are forced to be nonpositive so that actual output must be below or equal to potential or best-practice output. The alphas are the estimated values of the three parameters estimated. Labor services are measured in unskilled equivalent labor days; each skill category is weighted by the ratio of its wage rate to the unskilled wage rate. Capital is an annualized service flow, assuming 10% return and economic lifetimes varying according to new or used machinery or buildings. Value added is estimated from gross sales and the percentage of costs not represented by intermediate purchases and services.

To capture the impact of allocative inefficiency, CBI estimated a measure of profitability, the social benefit-cost ratio ($SBC = VA/r^*K + w^*L$), valuing factor costs at shadow prices. Border prices of output were unavailable, and the shadow price of labor differed by a small margin from wages paid (reflecting the fact that during the 1970s real wages remained constant or declined). Only in the case of capital did differences with market prices arise. CBI assumed that the social opportunity cost of capital of 10% was higher than the average private cost because of the low cost attributed to self-financed investment in a highly inflationary period.

In addition to the conclusion on the lack of a systematic relation between size and technical efficiency, CBI's study of the patterns of TEI and benefit-cost indices suggested the following patterns of efficiency and profitability. First, setting aside the firms in difficulty, the average entrepreneur was earning a healthy return (51% on average for the rate of return to total capital employed by the firm), far more than he/she would earn in alternative employment. One-sixth of metalworking firms did not cover the full cost of inputs, although they managed to cover their variable costs , i.e., working capital and labor costs. The continued existence of firms with such low returns, may reflect overestimation of the opportunity cost of the entrepreneur's labor or capital--estimates based on averages for persons with characteristics similar to those of the entrepreneurs and for capital obtained from similar sources. Entrepreneurs, particularly former blue-collar workers, may underestimate the cost of their own time and because of their background set relatively modest income expectations.

Second, allocative inefficiency was not likely to be a factor confounding TEI differences across firms. CBI (1987, p.103) examined whether price differences reflected quality variations or differences in the market power of firms, noting that, "a high product price [for comparable quality] would tend to be reflected (incorrectly) in our estimates as a high level of technical efficiency and (correctly) as a high PBC." CBI discounted absolute price differences based on evidence of the entrepreneur's estimate of how much higher or lower competitors' prices and quality were. Nevertheless, in regressions examining the variation in TEIs, CBI used dummy variables to account for firms' product prices differing from their competitors. These variables were statistically significant; reported lower product prices reduced technical efficiency 20%, while higher prices increased it by 12%. Contrary to expectations, the usual variables, such as entrepreneur's education and experience, and degree of labor mobility, contributed little to the model's explanatory power.

Page (1984) also explored the relationship between size and technical efficiency using Indian data covering four industries (printing, soap, shoes, and machine tools with 66, 48, 99 and 78 firms, respectively). Only in the case of machine tools did Page find that relative technical efficiency increases systematically with size of firm, based upon pairwise analysis of variance. Firms with fewer than 10 employees produced about 55% of best-practice output compared with 70% for those with more than 50 employees (Page, 1984, p. 139). Unlike other industries sampled, economies of scale were related to the engineering characteristics of the production technology and were not offset by other firm/managerial characteristics impacting on technical efficiency that may vary across large and small producers (as measured by number of employees). Plant scale economies, no doubt related to the requirements for varied capital machinery in the production process, made it difficult for smaller firms to operate efficiently in this industry, which is perhaps the most sophisticated of the metal-mechanical sector.[2]

Page (1984) also used a deterministic frontier production function, but expanded the measured inputs to utilize a four-factor translog form including capital services, unskilled and skilled labor, and material inputs. As noted in the previous chapter, this flexible form has the advantage of imposing relatively few a priori restrictions on the structure of production and accommodates a variety of substitution possibilities. Its very flexibility, however, requires the imposition of additional constraints to assure that the frontier is well behaved, namely CRS, monotonicity (nonnegative marginal products), and concavity. Under these constraints,the author claims, the resulting TEIs yield a set of transitive multilateral total factor productivity indices. Transitivity makes these TEIs particularly useful for making multilateral (rather than just bilateral) comparisons of productivity for cross-section and time-series data, i.e., index I satisfies the transitivity test

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[2] Plant scale economies are also suggested by the size distribution of the sample, which is admittedly biased towards larger firms in all four industries studied. Over one-quarter of machine tool firms sampled had more than 50 employees compared to 7% to 10% for the other industries.

if for units $k, l, ..., m$ if $I_{kl} = I_{km}/I_{lm}$ (Caves et al., 1982, p. 74). Page therefore uses the translog TEIs to examine "both the relationship between actual and best practice productivity at any one data point and level differences in total factor productivity among pairs of observations" (Page, 1984, p. 133). Because Page does not have time-series data, the TFP lacks its dynamic context which links it to technological progress.

Page's (1984) translog frontier is given as

$$ln\ \underline{y}(s) = \alpha_0 + \Sigma_n \alpha_n\ ln\ x_n(s) + 1/2 \Sigma\Sigma \beta_{mn}\ ln\ x_n(s)\ ln\ x_m(s)$$

where $\underline{y}(s)$ and $x_n(s)$ are indices of maximum potential output and of input levels, respectively. He expressed input levels as ratios to the geometric mean of the sample in each industry. Because the translog is a second-order approximation to a true production function, scaling inputs to sample means sets these means as the point of approximation. Page's labor input included skilled (white collar, paid family, and skilled workers, and working proprietors) and unskilled (semi-skilled and unskilled workers, unpaid family and casual labor) labor services and expressed in person days. For the capital input he used the annualized flow of services, valued at historical costs and assuming a 10% discount rate with economic lifetimes varying by asset category. He also used gross output rather than value added, and defined material inputs as the value of all purchased material and service inputs.

Page also derived firm-specific TEIs from the linear programming problem, minimizing the deviations from the frontier subject to the constraints that all observations lie on or above it and the translog is well behaved. Page tested the "fit" of his specification of the technology by comparing the difference in the value of the objective function between restricted and unrestricted frontiers. This comparison showed that the cost of constraining the frontier to be linear homogeneous and convex is modest, from less than 0.5% in the case of machine tools to 2.5% in the printing industry.

Given the lack of quantity data, Page assumed prices accurately capture quality differences and used value figures in lieu of physical quantities. He, however, used conventional production function estimation to consider possible sources of allocative inefficiency potentially biasing his TEIs. Using joint estimation of a translog production function and the share equations, Page examined differences in factor proportions (whether they might arise from product or factor price differences) and tested his specification of the production technology. The results, reported in a larger study with Little and Mazumdar (1987), illustrate the complexity in sorting out the technical characteristics of production without complete price and quantity data.

Like CBI, Page also examined with multiple correlation techniques the relationship between estimated TEIs and omitted (managerial abilities) and ill-defined inputs (vintage of capital, quality of workers). To further test the relationship between size and technical efficiency, Page regressed a variety of firm and worker characteristics including size on the logarithm of firm TEIs. He concludes that the experience and stability of workers were most important in explaining technical efficiency differences across firms; "a ten percent increase in the average experience of the labor force results in a two percent increase in the Farrell index (and hence [under CRS], to a two percent decrease in unit costs)" (Page, 1984, p. 144).

By including the experience of workers (measured as the mean of the distribution of years of experience with the firm by regular employees) rather than just the firm's management, the focus turns to the abilities to organize, develop, and keep good workers. Employee firm experience together with general entrepreneurial experience and age of firm, both of which exert an unexpected negative impact on technical efficiency, explain about 40% of TEI variation in the machine tool industry. Page suggests that the negative sign of these coefficients reflected the importance of modern managerial methods and latest vintage capital in the efficient operation of firms in a technologically sophisticated industry like machine tools. In addition, capacity underutilization, proved not to be important in TEI variation. Intuitively, we expected capacity utilization to be important in machine tools where the firm faces more directly the indivisibility of capital. Part of the problem may lie in that Page operationalized this variable as a dummy variable, indicating higher output value (in constant prices) three years prior to the survey year.

The firms in the machine-tool industry produced mainly machine-shop lathes, milling machines, and drill presses. Having already found evidence of plant scale economies, in the cited larger 1987 study, Page and his co-authors tested for the possibility of dual production technologies. If firms were not employing the same technology, then, the frontier as a standard was not applicable. The analysis of capital-labor and skilled-unskilled worker ratios showed no systematic patterns to suggest a break between workshop and factory methods associated with size.

This supports Dudley's (1983) findings rejecting the existence of dual production technologies in the metal-mechanical sector in Colombia. Within size-group variation in these ratios was large and smaller firms tended to be organized as small-scale factories. For example, the 10 to 25 employee size group, representing slightly over one-third of the sample, showed both high skill and capital intensity. In contrast, the largest size group with over 100 employees, representing one-sixth of the sample, seemed to substitute rather than complement skilled labor with capital. This group exhibited the highest capital-labor ratio, but the lowest skilled-unskilled worker ratio. We suspect that product group and quality as well as machinery differences may be relevant in explaining these patterns. Larger firms may aim towards a relatively more standardized product manufactured with both simpler and automated machinery to reduce the requirements of skilled labor.

To examine further these differences in technology, the authors incorporated the plant vintage variable into their translog production model and found that each additional year in the age of the capital stock reduced TFP (i.e., TEI given the static interpretation) by 2%-3% (Little, Mazumdar and Page,1987, p. 181). Moreover, they found that even in the case of machine tools smaller plants do not generally have older vintage capital (incorporating less efficient technologies) and, in turn, lower productivity.

CBI's (1987) and Page's (1984) conclusions on the patterns of TEIs suggest size and technical efficiency are related to the sophistication of the production technology. In metalworking firms such as CBI's agricultural and kitchen equipment producers, capital indivisibilities are important. In a more sophisticated metal-mechanical industry such as machine-tools, capital demands are greater in terms of exploiting scale economies. Nonetheless, according to Page (1984) other firm characteristics, particularly the experience and stability of workers, are also important in determining firm efficiency. He, however, did not link this result with information about Indian labor legislation or other factors affecting labor market conditions. These conditions will prove key to our explanation of technical efficiency patterns and changes in CBI's sample of Colombian metalworking firms in Chapter 5.

In terms of efficiency measurement, these results confirm the importance of verifying our basic assumptions regarding the form of the production frontier as the standard for efficiency rankings. On average, these deterministic frontier applications provide a lower-bound estimate of average technical efficiency from 56% of best-practice output for CBI's metalworking sample to 69% for Page's machine-tool firms. Stochastic frontiers would no doubt yield higher estimates of technical efficiency once random error is taken into account. However, as Caves and Barton (1990) argue in their comparison of deterministic versus stochastic frontier applications, results suggest there is substantial scope for improvement of technical efficiency.

Sources of Productivity Change

As noted in the introduction to this chapter, Nishimizu and Page (1982) applied the tools of efficiency measurement in a dynamic context. They measured technical efficiency improvements as the productivity increment from getting closer to the frontier. Technical change, then referred to the changes in the frontier over time. This means that the TFP residual, interpreted as technological change since the work of Solow (1957), must also include a component reflecting the efficiency with which technology is applied. These authors claim that distinguishing between technological change and technical efficiency is important in formulating effective policies to improve productivity. For example, low or even negative rates of TFP change may coincide with technological progress but deteriorating technical efficiency. Best-practice firms may be shifting outwards the industry production frontier while other (interior) firms fall further behind this shifting frontier. Moreover, as the average efficiency of firms in an industry falls, the potential for the industry's productivity growth may also fall.

In their decomposition of TFP change in Yugoslavia, Nishimizu and Page (1982) concluded that most of the gains in TFP were attributable to improved technical efficiency and that greater gains were possible in this area. Although admitting no neat distinction between technical efficiency and technological progress in theory or practice, they directed policy attention to sectors most plagued by problems of investment planning and implementation, lack of technical experience, and poor management and organization. This technical assistance would help technically inefficient firms to catch up with the country's best practice.

Working with time-series data from Yugoslavia's regionalized sectoral production accounts, Nishimizu and Page (1982) estimated deterministic translog industry production frontiers utilizing linear programming. Under conventional techniques, the appropriate estimation method for a translog production function would involve joint estimation of the parameters of the function with the system of share equations relating each input's cost share to its price. If factor price data are unavailable or if the assumptions of profit maximization in competitive factor and product markets fail (which provide for the equality of observed factor income shares and output elasticities), joint estimation is precluded. Like Nishimizu and Page (1982), most analysts have turned to frontier methods.

To estimate a sector's production frontier, the linear programming problem follows the simpler case described above, but this time minimizing the sum of deviations over time (t) periods as well as units (s)

$$min\ \Sigma_t \Sigma_s [(\underline{\alpha}_0 + \underline{\alpha}_t t + 1/2\ \underline{\beta}_{tt} t^2) + \Sigma_m (\underline{\alpha}_m + \underline{\beta}_{mt} t)\ ln\ x_m(s,t)$$
$$+ 1/2\ \Sigma_m \Sigma_n \underline{\beta}_{mn}\ ln\ x_m(s,t)\ ln\ x_n(s,t) - ln\ y(s,t)]$$
$$s.t\ \ ln\ \underline{y}(s,t) \geq ln\ y(s,t)$$

to assure the observed input-output combinations lie on or below the frontier (denoted by the underline).

The data used to estimate the three-factor frontier include series of gross output, material input, capital input based on the replacement cost of the net capital stock, and labor input based on the number of employed persons. Each series had data for thirteen years (1965-1978), twenty-six social sectors, and eight regions. Nishimizu and Page (1982) used gross output rather than value added to account for productivity changes attributable to intermediate inputs from their improved quality or external economies.[3] Nishimizu (1979) argued that the omission of intermediate inputs is particularly serious in disaggregated analyses in which the contribution of an industry to national TFP change is the sum of its own productivity increases as measured by the increase in its delivery to final demand, and the "magnification" effect of productivity increases transmitted through intermediate deliveries to linked industries. More fundamentally, the appropriateness of excluding

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[3] The use of value added as a measure of real output requires assuming separability between material and non-material inputs such that the production function $Q = f(K,L,M)$ can be written

$$Q = g\ (v(K,L),\ M) \quad \textit{where } v \textit{ represents real value added}$$

As stated by Fuss et al. (1978, p.244), "separability is characterized by the independence of the marginal rate of substitution between a pair of inputs [in this case, capital and labor] from changes in the level of another input [in this case, material inputs]." In deriving real value added (v), nominal value added (V) is influenced by the prices of both output (p_Y) and the intermediate input (p_M) as in $V(K,L,p_Y,p_M)$. Given these prices vary in strict proportion, v is

$$v\ (K,L) = V\ (K,L,p_X,p_M,Q_p)$$
$$\textit{where } Q_p = a\,p_X + b\,p_M \quad \textit{defines the price index.}$$

defining the commonly used method of double-deflation.

material inputs rests on the validity of assuming either perfect or no substitution between purchased inputs and primary factors (labor and capital).

The translog frontier and its corresponding index numbers allow the authors to measure a region's relative technical inefficiency in a given sector by the ratio of the indices of observed to potential (defined by the frontier parameters) output levels. This ratio is obtained as the antilog of the slack variables in the first constraint equation limiting all observations to lie on or below the frontier. The shift of the production function is given by the change in the frontier parameters over time. A region's rate of technological progress in a given sector is calculated by combining the frontier parameters with observed input level as in

$$TFP' = \frac{\partial ln\ y(s,t)}{\partial t} = \alpha_t(s) + \beta_{tt}(s)t + \sum_m \beta_{mt}(s)\ ln\ x_m(s,t)$$

for each year and computing simple averages for consecutive pairs. In this equation α_t is the rate of TFP change at the normalization point.[4]

Instead of setting sample input means as the point of normalization around which to expand the Taylor series--the usual practice in most translog applications including Page (1984) above, the authors chose the most developed region, the Republic of Slovenia, as the normalization point . If the relative performance of industries varied across regions, this choice could have biased the estimated sectoral frontiers given that the early terms of the Taylor series provide a good approximation to an arbitrary production function only in the neighborhood of the chosen normalization point. Also, the imposition of CRS for at

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[4] If the normalization point is appropriately chosen, the α_t coefficient should be nonnegative. β_{tt} can take positive, negative, or zero values for increasing, decreasing, or constant rates of TFP change. The share elasticities of inputs with respect to time, β_{mt}, define the bias of TFP change. In a micro application of this methodology, Little, Mazumdar, and Page (1987, p. 150) explain the interpretation of the values of the β_{mt}'s: "If a share elasticity with respect to time is positive (negative), the corresponding value share increases (decreases) with time, and the bias is interpreted as input using (saving). If the share elasticity is zero, the share is independent of time, and if all share elasticities are zero, the pattern of productivity is Hicks neutral." However, as we note in our review below, given the aggregated data upon which Nishimizu and Page's (1982) estimates are based, it is unclear how these estimates of bias might be biased by the other technical characteristics of production.

least some sectors may have biased TFP results in favor of regions where larger or smaller firms predominate.

In addition to the potential problems with the CRS specification and the choice of normalization point, there is the usual problem of all deterministic frontiers in failing to distinguish random noise from technical efficiency. However, the more serious sources of bias relate to the fundamental measurement problems noted in Chapter 2 and repeated in this chapter. First, incorrect assumption of similar technology when production units are functioning on different production surfaces will vitiate the frontier as a standard of comparison. We find the concept of an average (aggregated) sector-wide technology difficult to reconcile with marked subsectoral differences. As Tybout et al. (1989) note, at this level of aggregation, TFP studies cannot distinguish between technical efficiency, capacity utilization and scale effects. Moreover, any attempt to examine the potential bias from allocative inefficiency, as described earlier, would have little meaning at this level of aggregation. It is no wonder subsequent sectoral studies, such as the one by Caves and Barton (1990), have relied on plant-level data and stochastic frontiers when unit-specific efficiency indices are not needed.

Second, incomplete specification of measured inputs will incorrectly reflect the productivities of factors. Without considering vintage effects, the authors' use of replacement costs for valuing capital punishes industries and regions with older capital. Similarly, the lack of adjustment for capital and even labor (hours worked) utilization may further bias TFP estimates downward for regions with underutilized capacity.

The work of Cornwell, Schmidt, and Sickles (1988; henceforth CSS) shows a theoretically appealing way of incorporating the stochastic component to Nishimizu and Page's (1982) dynamic model of technical efficiency change. As explained in Appendix B, CSS's variance components model estimated with panel data gets around the limitations that have impeded stochastic frontier applications--the difficulty of deriving unit-specific TEIs, the seemingly arbitrary choice of an error distribution for the nonnormal error component capturing technical inefficiency, and the assumption that factor use is uncorrelated with technical inefficiency. Moreover, the CSS model allows technical efficiency to vary in time as well as across firms, i.e., allowing variation in slopes as well as the intercept. Their application to the US airline industry suggests that the increase in efficiency levels over time, which lead to more uniform productivity levels across firms, was related to the competitive pressures brought about by deregulation of the industry.

Building a sophisticated model from a rather complete data set, the CSS study provides positive evidence of the early benefits of the policy of deregulation in the industry. Despite the robust results, they require additional explanation. Because TFP, by definition is disembodied, its sources are difficult to identify. It's no wonder the TFP has been criticized as being "a mysterious manifestation of grace" (Harcourt, 1972, p. 48); we can measure it, but we don't know where it comes from. As in most other stochastic frontier applications, the main focus is methodological. It seems that the authors could have strengthened their conclusions with an analysis of changes in managerial and other practices that might help to explain efficiency trends.

CONCLUSIONS

In this chapter we reviewed the methods of efficiency measurement, specifically the concept of the frontier or best-practice production function, which in a dynamic context helps us to account for an important source of bias confounding estimates of TFP change. Although our review of empirical work focused exclusively on a specific type of error in optimization, that is, technical inefficiency or the failure to maximize output with given inputs, we described how an examination of TEI patterns by size groupings provides information on the efficiency of the scale of productive units. Similarly, we can complement this information with evidence of differences in factor use and output prices to capture allocative inefficiency indirectly, which we cannot study directly without complete input price and quantity data. As we noted in Chapter 2 with reference to adjusting TFP estimates for capacity underutilization, we often do not have the option of applying the most theoretically sound method.

Our empirical work in Chapter 5 is guided by the following main conclusions from our review of empirical frontier applications. First, the choice between frontier models involves trade-offs between model features--the more complex and elegant the model, the greater the data and estimation requirements. Second, even with the more statistically rigorous models, the processes we are trying to model are complex and require corroborating information to support results. Without such information, our efficiency measures lack the context and specifics that might make them useful for policy making.

Only recently are comparative studies becoming available to give us an idea of the sensitivity of results to the frontier methodology. For example, Corbo and de Melo (1986) use Chilean 4-digit, establishment-level, census data to compare nonparametric and parametric deterministic and stochastic frontiers. Given data availability, the choice is between deterministic parametric and stochastic frontiers. Examining rank correlation coefficients among different TEIs within sectors (across firms), Corbo and de Melo (1986, p. 27) find that within the Cobb-Douglas specification, these techniques "yield broadly similar results;" Pearson correlation coefficients range from 0.45 in dairy products to 0.96 in wine industries with 0.86 for non-electrical machinery.[5] These findings suggest that within sectors we are not likely to obtain radically different rankings for firm technical efficiency comparisons from using the simpler deterministic parametric frontier compared to the more complex stochastic frontier. Since we will be comparing TEIs across firms in the same industry, this study suggests our choice of the deterministic programming frontier is not likely to affect our conclusions.

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[5] These correlation coefficients correspond to the comparison between the deterministic parametric and the stochastic frontier where the latter is based on the assumption of a half-normal nonnormal error distribution. However, for most sectors, the results are similar based on an exponential error distribution (Corbo and de Melo, 1986, pp. 24-25). This is not the case for the comparison of these frontiers across sectors.

CHAPTER 4

THE COLOMBIAN METAL-MECHANICAL SECTOR

In this chapter we review the key aspects of the macroeconomy in 1977 and 1989 to highlight the difficulties and opportunities in demand and supply faced by the sector during those years. This review will provide the hypotheses to be examined in the next chapter. First, however, in order to provide the historical context for the survey years, we focus on the rise of industries producing nonelectrical machinery (ISIC 382), specifically kitchen and agricultural implements, which are the subject of our firm-level productivity analyses.

THE RISE OF KITCHEN AND AGRICULTURAL EQUIPMENT PRODUCERS

The 1940 Development Plan clearly placed import-substituting industrialization as the centerpiece of development policy. Its establishment of the steel and iron works at Paz del Río laid the foundation of the Colombian metal-mechanical sector. Domestic production of iron and steel was promoted through protective tariffs and the provision of discounts and financing for high volume buyers. However, it was not until the mid-1950s and through the 1960s that industrial policy targeted metalworking for import substitution. Repeating a pattern established since the turn of the century, stagnant coffee exports created imbalances in the external sector prompting increased tariff protection to contain balance of payments deficits. During this period metal products, machinery, and transportation equipment registered growth rates above 9%, outperforming industry as a whole; their import requirements, however, ranged about 80% of raw materials utilized.

Dudley's (1983) disaggregated analysis of the economic performance in the metal-mechanical sector during 1959-1966 highlights the differences within the sector. Given the variety, complexity, and discontinuities of production processes in the sector, Dudley posited that the more sophisticated processes yield higher productivity increments in terms of learning-by-doing. Confirming his expectations, machinery producing industries registered higher labor productivity gains than those in metal products. In terms of our sample industries, kitchen and agricultural equipment registered productivity gains in terms of value added per worker of 5% and 116%, respectively, compared with the sectorwide average of 51% over the eight-year period. Furthermore, Dudley found that most learning is output-dependent in the case of kitchen equipment, reflecting the technology's relative simplicity not only in terms of production operations but also its organization and administrative requirements. In contrast, for agricultural equipment, learning by the firm was largely a function of time and accumulated experience.

These productivity trends highlight differences in market structure between these industries. In the 1960s, the mechanization of agriculture fostered the demand for agricultural equipment and the birth of small firms. These firms were established by former workers with experience in the few large firms that traditionally dominated the Colombian market--large wholesalers such as the Colombian subsidiary of General Electric, AMACHICO, a licensee of Caterpillar, and Apolo which also produced industrial and mining machinery. In the case of kitchen equipment, there was no national production even by foreigners prior to the 1960s. Pioneering firms in this industry had to undergo a period of learning characterized by trial and error in copying existing imports.

Berry's (1983) estimates of capital and total productivity indices for 1969 give us an idea of the relative performance of the sector with respect to all industry. His results reproduced in Table 4.1 show that the metal-mechanical industries registered higher value added per unit of capital than the average of all industry. However, this pattern changes when value added is converted to world prices using effective rates of protection. Electrical machinery, a heavily protected metal-mechanical subsector, was an extremely inefficient user of capital (see second column of Table 4.1). At world prices, only nonelectrical machinery performed above the industry average confirming its relative efficiency and competitiveness with imports in 1969.

TABLE 4.1

BERRY'S RELATIVE TOTAL FACTOR PRODUCTIVITY ESTIMATES FOR THE METAL-MECHANICAL SECTOR: 1969

(thousands of pesos)

Industry	Capital Productivity		Total Factor Productivity	
	Market Prices	World Prices	Market Prices	World Prices
Basic Metals	0.152	0.061	0.681	0.403
Metal Products	0.322	0.291	0.965	0.838
Nonelectric Machinery	0.342	0.368	0.939	1.266
Electrical Machinery	0.317	negligible	0.951	negligible
Transport Equipment	0.370	0.052	0.880s	0.150
Industry Average	0.290	0.217	1.000	1.000

Capital productivity= VA/K; VA =Value added and K= capital stock including financial capital. Total Factor Productivity= VA/(Kr+W(O/R)); r = average return to capital in factory industry (excluding beverages and tobacco) calculated at 14.7%; W = wage bill; O = number of occupied workers; R = number of remunerated workers. For valuation at world prices value added is adjusted using Hutcheson's effective rates of protection.

Sources: Berry, 1983, Table 2.18, pp.64-65.

In 1967 the balance of payments crisis generated by increasing industrial demands precipitated a change in policy. With Decree 444 Colombia moved towards export promotion and diversification to balance out the import substitution system of tariffs, quotas, and prior deposits. To avoid repeating the sudden devaluation of September 1965, President Lleras waited until foreign exchange reserve levels were restored before breaking the stand-off with foreign creditors and agreeing to a crawling peg regime and gradual import liberalization (Díaz-Alejandro, 1976).

Exchange rate flexibility removed the bias against tradeables, allowing the adjustment of exporters' production costs to the export product price in pesos. During 1967-1971 the peso was devalued in real terms by almost 20% with respect to the US dollar; however, removing this source of anti-export bias did not mean import liberalization. Protectionist mechanisms, though less severe and gradually moving toward greater uniformity, remained in place and the reforms added greater regulation of foreign investment and technology transfer (i.e., limiting profit remittances and royalties).

Another key provision of the trade reform was the provision for global licensing introduced in 1969. It allowed importers to apply for a single global license for a variety of capital goods and subjected this package to a 5% uniform tariff. During 1972-74, global licensing projects represented about 6% of the value of registered imports. By 1975 this share increased to almost 11% and these licenses accounted for about one-third of the total value of capital goods imports (World Bank, 1983, estimated from INCOMEX data on pp. 187 and 191). On one hand, global licensing promoted the renovation of the capital stock particularly by larger firms (dealing directly with foreign distributors) who then created a market in second-hand equipment to supply the rapid growth of small firms in the mid-1970s. On the other hand, it undercut domestic capital goods producers, admittedly few in number at this early stage, who had to pay much higher tariffs for imported inputs as well as contend with the unreliable quality of domestic steel products.

Despite rates of growth above 8% for the early 1970s, many analysts argued that the export burst was founded upon higher capacity utilization and did not change the secondary role of exports as an outlet for excess production (Adda, 1986; World Bank, 1983; Wogart, 1978). Indeed, as Díaz-Alejandro (1976) concluded, the availability of foreign exchange allowed authorities to cease stop-and-go macroeconomic policies. This stability encouraged business to bring previously idle resources into production. Díaz-Alejandro's (1976, p.208) comparisons of relative sectoral shares for 1962-1973 lent little support to an interpretation crediting the 1967 export promotion drive with a reallocation of resources from less (nontradeables) to more productive (tradeables) sectors; he noted "the Colombian experience indicates that drastic import liberalization is neither a necessary nor a sufficient condition for export growth."

The 1970-74 economic program made construction the leading sector and for the first time economic policy was linked to the irreversible urbanization trends through the provision of badly needed urban housing. President Pastrana's Four Strategies Plan maintained that given the underutilization of capital and labor due to insufficient demand, there was a need to push relatively labor-intensive sectors with few foreign exchange requirements. In addition to the construction sector, the Plan also promoted export diversification and sought to raise agricultural productivity through land redistribution and improve the distribution of income through progressive taxation. These goals did not prove complementary. Adda (1986) charges that the government's promotion of competitive commercial agriculture for export effectively set aside land reform and even encouraged rural exodus. While some migrants were absorbed in the much-needed task of building housing, others exerted an equally necessary dampening effect (given inflationary trends) on real urban wages.

To channel resources into construction, the Plan created the UPAC system (*unidades de poder adquisitivo constante*--units of constant buying power) to capture domestic savings by introducing the indexation of savings, Certificate of Deposits (CDs), and term deposits. This increased the contribution of household savings to investment from 6% in 1972 to an average of 25% after 1973 (World Bank, 1983, p. 165). The resulting construction boom set the stage for the rapid growth of firms producing kitchens for domestic and industrial use. After 1974, however, industrial growth was interrupted by the tripling of coffee prices in 1976-1977, and the repatriation of profits from illegal drug exports. The construction boom, in the context of an already prosperous domestic economy sustained by the export bonanza, fueled inflation. As we shall see below, the government's efforts to dampen inflation, while liberalizing trade and the financial sector, inadvertently created obstacles for industry and machinery producers in particular.

Key Aspects of the Macroeconomy in 1977 and 1986

Having provided the historical perspective above, we begin this section by highlighting the key aspects of the Colombian macroeconomic context during the period between the survey years, 1977-1986. We are then able to present a more detailed review of the demand and the supply-side impacts upon the economic performance of firms in nonelectrical machinery. Given the lack of four-digit ISIC data, we focus on nonelectrical machinery (ISIC 382), a close proxy for capital goods, which includes our sample industries, agricultural and kitchen equipment.

The Ups and Downs Between 1977 and 1986

We noted how economic growth followed the ups and downs of the coffee cycle as the balance of payments dictated the movement to and away from import liberalization. In the 1970s and 1980s, the problems of inflation, a weak financial sector, and world recession aggravated these swings. In 1970, the rate of inflation was 6.8% as measured by the consumer price index (CPI for blue-collar workers); by 1974, it was up to 25.2%; and by 1977, it peaked at 34.8% (see Table 4.2). Although President Lopez set out to liberalize the financial sector in 1974-75, he reversed these reforms in 1976-77 in an effort to contain liquidity from the tremendous increase in foreign reserves. Initially, the reforms limited the Central Bank's developmental role, reduced reserve requirements and forced investments, and conferred upon banks greater discretion over the management of their assets. With these measures, he had hoped to alleviate the problems of credit rationing and an historic low personal savings rate (averaging below 1% of GDP). With the counterreform, Lopez tightened credit by increasing reserve requirements, created new instruments for forced savings (i.e., exchange certificates), increased securities issues, and cut public investment. These measures produced dramatic results as the contribution of central and commercial bank credit to the growth in the money base fell during 1976-1979 from 26.2% to 15.2% and from 46.5% to -33.6%, respectively (Adda, 1986, p. 141).

According to the World Bank (1983, p. 163), this financial counterreform "by repressing the organized financial market, stimulated the growth of non-regulated financial instruments and intermediaries" and increased the importance of credit at preferential rates. In effect, these policies created a two-tier financial system, one heavily regulated and the other free. The regulated tier was characterized by high reserve requirements and forced (or directed) investments which claimed as much as 80% of a bank's loanable portfolio and were used to allocate credit to priority sectors at preferential rates. Access to such rates encouraged the concentration and inefficiency of banking institutions, which were legally shielded from foreign competition .[1] With respect to the unregulated or extra-bank intermediaries, they experienced spectacular growth making even their certification for incorporation very difficult. During this period of restrictive financial policy, this group created a variety of innovative and highly-leveraged financing instruments whose impacts were to be felt with the recession.

TABLE 4.2

SELECTED MACROECONOMIC INDICATORS: 1977-1986

(percent)

Year	GDP	Real Exchange Rate	Blue Collar CPI year-end change	Fiscal Deficit share of GDP	Rate of Urban Unemployment
1977	4.2	85.7	34.8	(1.3)	9.4
1978	8.5	85.5	16.7	0.1	8.2
1979	5.4	81.7	24.8	0.2	8.9
1980	4.1	83.5	27.2	2.8	9.2
1981	2.3	81.6	28.1	5.2	9.6
1982	0.9	75.6	24.6	6.0	10.0
1983	1.6	73.6	26.7	7.6	10.7
1984	3.4	79.9	18.3	6.3	13.9
1985	3.1	91.4	22.7	3.9	15.1
1986	5.1	108.5	20.7	0.5	13.1

Real exchange rate calculations are shown in Table 4A.1 in Appendix C. Parentheses denote a surplus in the case of fiscal deficit figures.

Sources: Banco de La República *Revista del Banco de La República*, DANE *Boletín de Estadística*.

Despite the tight credit policies before 1979, the metal-mechanical sector and nonelectrical machinery industries reached their peak output levels in that year (see Chart 4A.1). However, by mid-1980 with the collapse of coffee prices, the Colombian economy was on the road to stagflation. President Turbay (1978-82) continued import liberalization and stepped up open-market operations to contain inflation. Having begun an ambitious

[1] Colombian banks have had little incentive to improve management and reduce their high operating costs. World Bank (1987, p. 73) estimates of the financial sector's ratio of operating to total costs of 6% compares badly with the 3-5% for countries in similar stages of development. A factor in these high costs is the lower level of technological development in communications which are provided by the state company, TELECOM which has been unable to modernize or properly maintain its equipment.

public investment program in infrastructure and energy, he seemed unable to scale it back and so external debt doubled during Turbay's tenure in office. As Lora and Ocampo (1986, p. 17) concluded, Turbay took steps contrary to what was needed to contain mounting balance-of-payments and fiscal deficits. With respect to the latter, the 1979 tax cut, more lenient tax administration, and expanding current expenditures accounted for over half of the fiscal deficit.

Aggravated by an overvalued peso, devaluation and recession in Colombia's main trading partners, Venezuela and Ecuador, precipitated the worst downturn in exports in 30 years. Table 4.2 shows that GNP growth fell from 4.1% in 1980 to 2.3% and 0.9% in the next two years, industry registered declines of 1.1% and 4.7%. From 74.4% in November of 1980 industrial capacity utilization bottomed out at 58.2% in 1981 (Arango, 1985, p. 247). The crisis extended to agriculture and the generalized recession in the productive sectors spread to the shallow financial sector. The financial crisis of 1982 forced the government to nationalize and guarantee the deposits of an important banking institution, the Banco Nacional, which was facing bankruptcy.[2] Moreover, the Mexican debt crisis of August, 1982 reduced Colombia's sources of external credit. Foreign reserves plummeted and the country found itself in the midst of recession and a severe balance-of-payments crisis.

To stem the crisis, the newly elected Betancur administration reversed the tide of import liberalization. By December of 1984, 83% of import items required prior licensing and 16.5% were included in the previously little-used prohibited category (see Table 4A.2 in Appendix C). To stimulate the economy during these years, the peso was devalued by 20% in real terms, the incentives for exports reinstated and strengthened, and the lines of credit reopened. This focus on external deficits did not meet the requirements for World

[2] The financial crisis came to a head again in 1984-1985 when the Superintendencia Bancaria forced institutions to present their books, leading to the nationalization of Colombia's largest commercial bank. In addition, special rediscount facilities and guarantee funds were created to recapitalize financial intermediaries. Several measures such as the automatic financing by the central bank of a part of the devaluation costs were offered to private companies to help their refinancing of foreign loans.

Bank credit and the re-opening of private financing. The adjustment program, in terms of the pace of devaluation and the reduction of the fiscal deficit, had to be stepped up and the mechanisms of protectionism phased out.[3]

As illustrated by Table 4.2, by the end of 1986 the government considered the adjustment program completed, recognizing its costs in terms of slower economic growth and the regressive impacts of reduced social expenditures. For 1986, GDP growth registered 5.1%, and unemployment was brought down to 12.3% from the 15.1% peak in 1985. Increases in coffee prices as well as more diversified exports of mineral and manufactured products allowed a US$2 billion increment over previous years export earnings. These events in the external sector helped to spread the recovery initiated in industry during 1984. Thus, authorities noted that Colombia had "entered a new stage with a strengthened external position, healthy public finances and a satisfactory rate of GDP growth, combined with moderate growth of money supply and prices, and with an unemployment rate which, although still high, showed a declining trend by year end" (Ministerio de Hacienda y Crédito Público, 1987, p. 9).

Demand-Side Impacts on Firm Economic Performance

In both 1977 and 1986, coffee export earnings stimulated aggregate demand and thereby the derived demand for capital goods. As a share of GNP, gross fixed capital formation (GFCF) averaged 5.4% over 1977-1986 with relatively little fluctuation (as measured by a standard deviation of only 0.6%). In contrast, trends for the machinery and equipment component of GFCF showed great instability, an overall lackluster performance except for the 1978-1981 period (marking the Turbay administration's heavy investment in

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[3] The main steps taken included: (1) quickening the pace of devaluation to reach parity by September 1985, (2) reducing export subsidies and beginning the staged reduction in tariff levels (see Appendix D), and (3) cutting the fiscal deficit by expanding the base of the value added tax, limiting the growth in public employment to 10%, and increasing the controlled prices for gasoline.

energy and infrastructure), and an increasing share of imports (from 64% in 1977 to 81% in 1986; see Table 4A.3 in Appendix C).

Chart 4.1 illustrates that this instability closely paralleled the growth rates for nonelectrical machinery output. These trends illustrate the impact of stop-and-go macroeconomic policies on business investment plans. More specifically, the dwindling participation of domestic machinery in GFCF reflected the discrimination against domestic capital goods: (1) in trade policies, (2) in bidding for government projects, and (3) from a lack of financing putting domestic producers at a disadvantage with respect to importers supported by own-country export credits. The first two issues need further explanation.

First, we noted the importance of global licensing, but the trade regime also favored imported capital goods through low tariff protection and the exemption of public sector purchases from import duties. Estimates of effective protection at the 4-digit ISIC level by the Departamento Nacional de Planeación (1982, p. 36) for 1980, probably the height of import liberalization, show that agricultural equipment (ISIC 3822) was provided with negative protection (-7%).[4] In contrast, for most items in electrical machinery (ISIC 383), largely classified as consumer durables, effective protection rates averaged above 30%. Second, domestic producers often lose government contracts to foreign suppliers because of their smaller production capacity and the inability to subcontract larger public purchases. In addition, for those capital goods in which the domestic firm does not face disadvantages related to volume, technology, or specific aid credits, the uncertainty and unreliability of government contracts is notorious.

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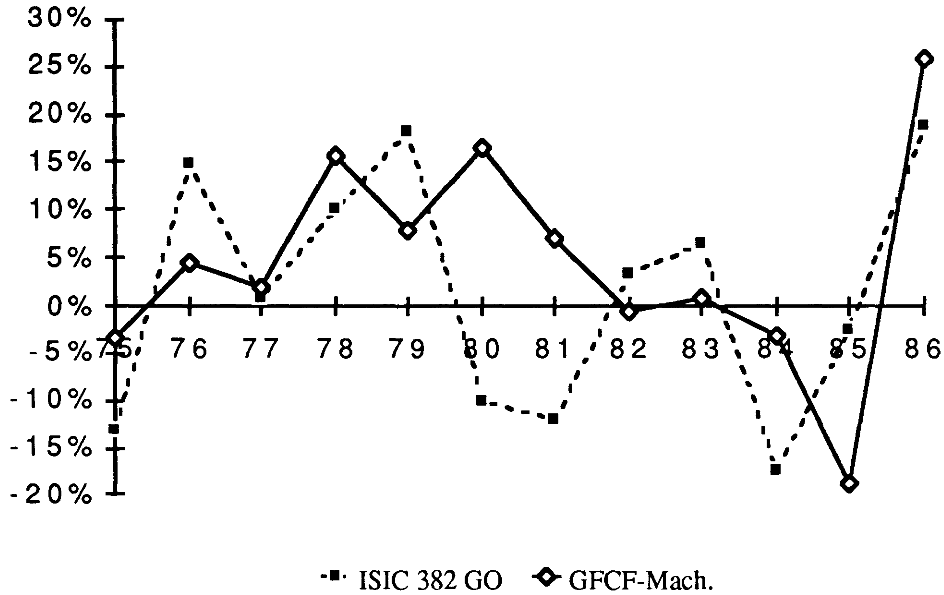
[4] Table 4A.2 in Appendix C illustrates the trends in nominal and effective rates of protection from 1979 to 1986. In all periods, protection granted to nonelectrical machinery (ISIC 382), the grouping most likely to coincide with capital goods, is consistently below the average of all product classes.

CHART 4.1

ANNUAL GROWTH RATES FOR NONELECTRICAL MACHINERY GROSS OUTPUT (GO) AND GROSS FIXED CAPITAL FORMATION (GFCF) IN MACHINERY: 1974-1986



Source: See Table 4A.3 in Appendix C.

The stimulus from export earnings during 1977 and 1986 for purchases of Colombian nonelectrical machinery were also dampened by the worrisome trends in the financial sector (detailed above) which affected the cost of industrial financing. World Bank (1983, p. 173) data show that interest rates generally outpaced inflation such that average real rates reached (or surpassed) 8% in 1977 and 1986. The causes behind this increase are complex and include external factors such as the parallel increases in world capital markets as well as internal factors, mainly the rise of the two-tier financial system and the crowding out by fiscal deficits.[5] Rates in the unregulated sector registered one to four percentage points above already high commercial rates.

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5 Other causes mentioned in the World Bank (1983, p. 173) report are: (1) the reductions in the relative price of manufactured products both worldwide and in Colombia (1974-1980), (2) the stabilization policies which tightened credit and shifted it to the unregulated financial sector where rates were higher (e.g., during 1973-1979 this sector's share rose from one-fifth to one-third of total industrial credit), and (3) the expectations of more rapid devaluation.

The instability engendered by these developments is demonstrated in Table 4.3. Although, the metal-mechanical sector performs only slightly below the industry-wide average for 1977-1986, its year-to-year fluctuations (indicated by the standard deviation) are much greater. More dramatic still, is the rather poor and highly erratic performance of nonelectrical machinery over this period.

TABLE 4.3

ANNUAL GROWTH RATES OF REAL OUTPUT BETWEEN SURVEY YEARS 1977 AND 1986

(percent)

	Average		Average		1977-1986	
Industry Group	1975-76	1977	1984-85	1986	Average	s.d.
GNP	3.5	4.2	3.2	5.1	3.8	2.2
All Industry	2.1	-0.3	7.6	8.8	3.9	5.0
Metal-mechanical	0.1	4.9	1.1	13.4	3.4	8.9
Nonelectric Machinery	0.9	1.0	-10.0	18.9	1.6	12.3

s.d.: standard deviation; Metal-mechanical group includes fabricated metal products (381), nonelectric machinery (382), electrical machinery (383), transport equipment (384), and scientific instruments (385).

Data Sources: Current peso figures (except GNP) from DANE's *Anuario de Industria Manufacturera* deflated with Banco de la República's *Revista del Banco de la República* wholesale price indices to convert to 1975 prices (see Table 4A.4 in Appendix C).

Although the 1977 growth in output for these industries was barely positive, this year marked a peak in the share of output exported (18%). The recession cut these exports in half and by 1986 barely 8% of nonelectrical machinery output was exported.

Supply-Side Impact on Firm Economic Performance

For the entire industrial sector, the trade regime is an important determinant of the cost and availability of inputs. For metal-mechanical producers, iron and steel products, motors, and electrical components are important intermediate inputs, and machine tools and other metalworking machinery are key capital goods. Domestic production in the first two categories has been contributing an increasing share of supply, although users rely on imports to satisfy more stringent quantity, variety, and quality specifications. We mentioned above the mechanisms for the negative effective protection afforded to some capital goods producers and described the tightening of import controls in the early 1980s.

In terms of the relative accessibility of capital goods producers to imported inputs, 1977 was clearly a better year than 1986. In 1977 a majority (52%) of items were classified in the free import list. By 1986 this share had dropped to 46%. Perhaps more importantly, according to the data gathered by Cubillos and Torres (1987), the differences in the rates of effective protection (a measure which takes into account the nominal protection accorded to intermediate products) between inputs and final products increased from a range of 3- 8% for nonelectrical machinery (see Table 4A.1 in Appendix C). Moreover, the overvaluation of the peso (suggested by the real exchange rate in Table 4.2.) in 1977 provided a further incentive to importing.

These conditions had an impact upon the production decisions of nonelectrical machinery producers; between 1977 and 1986, they reduced their dependence on imported raw materials from almost 50% to 40% of materials consumed. In terms of the cost of these inputs, 1986 saw higher prices with respect to 1977. The raw materials and intermediate inputs price index registered its greatest increase over the decade in 1986 (see Table 4A.4). In the recession years, intermediate purchases declined to almost 50% of gross output during 1982-1983 before returning to the pre-recession average around 60% in 1986. As we demonstrate below, raw materials and intermediate input prices were not the only factor increasing the cost of production. High capital costs dampened investment in production, while the recession allowed firms to stop the profit squeeze by decreasing labor's share.

Declining Investment in Plant and Equipment

After a strong growth in the beginning of the period and a major slump associated with the first wave of the recession in 1981, 1985-1986 saw sizeable declines in fixed capital as measured by real book value as shown in Table 4.4. These figures are indicative of broad trends; we recognize this measure may underestimate the value of the capital stock given that entrepreneurs fear the tax liability consequences of reporting more realistic values. Over the 1977-1986 period, nonelectrical machinery averaged a modest 4% rate of growth in fixed capital. This average rate of growth, however, masks the absolute decline in the level of real fixed capital of almost one-third over this period. This decline proved long lasting; fixed capital remained at 80% or less of the 1977 level between 1981 and 1986.

TABLE 4.4

ANNUAL GROWTH RATES OF FIXED CAPITAL AND ITS PRODUCTIVITY BETWEEN SURVEY YEARS: 1977 AND 1986

(percent)

Industry Group/ Item	Average 1975-76	1977	Average 1984-85	1986	1977-1986 Average	1977-1986 s.d.
Fixed Capital (Real book value):						
Metal-mechanical	na	24.4	-10.5	2.3	1.2	11.7
Nonelectric Machinery	na	24.4	-11.3	11.2	3.9	34.9
Capital Productivity (Real output per peso of real book value):						
Metal-mechanical	na	-15.7	13.5	10.9	2.9	11.2
Nonelectric Machinery	na	-18.9	1.3	6.9	7.9	39.1

s.d.: standard deviation; Metal-mechanical group includes fabricated metal products (381), nonelectric machinery (382), electrical machinery (383), and transport equipment (384), and scientific instruments (385).

Data sources: Figures in current pesos from DANE's *Anuario de Industria Manufacturera* deflated with Banco de la República's *Revista del Banco de la República* wholesale price indices to convert to 1977 prices (see Table 4A.4 in Appendix C).

World Bank (1989, p. 72) estimates of aggregate (economy-wide) capital productivity from TFP indices show that capital productivity has been decreasing about 1.1% per year during 1976-1986. This together with their estimates of the incremental capital-output ratio, which has been increasing, suggests capital deepening in the Colombian economy. However, Table 4.4 shows that in nonelectrical machinery capital productivity has been fairly healthy for this period, reflecting the fact that this subsector is still fairly young.

We noted above the increasing real rates of interest, by 1986 commercial loans claimed a real rate of interest above 10%. This figure illustrates the intensity of lenders' inflationary expectations and contrasts with the barely positive rate for preferential credit. The high rates of interest were particularly damaging given industry's reliance on debt. The trend towards debt rather than equity financing, marked by the decline in new stock issues, reflected the growth of financial intermediation, the biases against equity in a tax system which disregarded inflation (until the 1979-80 reforms introducing full indexation), and the shallowness in the Colombian stock market. The tendency of product prices and profits to lag behind interest rates and debt service created short-term liquidity problems and forced firms to incur further debt or cease operation. In addition, as the main source of industrial credit, the *corporaciones financieras* (financial corporations), came to rely increasingly on short-term CDs, firm debt moved toward shorter maturities. Domestically, the UPAC system reserved long-term maturities for housing construction, while the public sector captured external long-term credits. The remaining short-term external credit became concentrated in a handful of the largest companies.

Echevarría's (1986) study of industrial financing points to the perverse effects of such trends. In 1983, a sample of firms studied spent five times more in investments such as real estate, purchase of short-term CDs, and speculation purchases to maintain high prices for company assets, than in investments in own plant and production. Thus, for larger firms, their access to preferential rates was linked to a decline in the rate of investment and a shift toward financial rather than real investment. As the World Bank (1983, p. 175) noted "these firms assumed the role of financial intermediaries and relent such funds, either directly or through other intermediaries and the unorganized market." For smaller firms, an important source of start-up capital, in addition to the unregulated financial sector, became the partial withdrawal of accumulated severance or *cesantía* benefits which was legalized in 1977. The *cesantía* fund equivalent to one month's salary for each year of employment for employees with 10 years or more seniority is due upon termination of employment or can be withdrawn as an interest-free loan, with the remainder earning 12% interest annually. While spurring the growth of small-scale enterprises, *cesantía* withdrawals presented a significant financial burden for existing firms.

Even more so than in 1977, the disparity between commercial and preferential credit translated into tremendous disparities in the cost of capital across firms. For firms with limited access to preferential credit, usually smaller firms, the cost of commercial loans might preclude investing in their plants, thereby delaying the replacement of obsolete machinery. Although the number of smaller firms (employing fewer than 100 workers) increased during 1977-1986 to comprise three-quarters of nonelectrical machinery producers, their share of net investment fell from one-third to one-quarter. We can see similar, though less pronounced, trends in other metal-mechanical subsectors, such as electrical machinery and transport equipment, where scale economies explain the dominance of larger capital-intensive firms (e.g., household appliance and automobile factories).

Declining Labor Share

The increases in the cost of intermediate and capital inputs described above put increasing pressure on firms to look for cost savings in labor or face a profit squeeze. Table 4.5 shows the share of value added (excluding indirect taxes) consumed by labor compensation (including fringe benefits), general expenses, and the remainder available for profits. Nonelectrical machinery producers managed to keep interest costs steady, contain the increases in general expenses, as well as reduce labor's share substantially to restore profitability levels close to the industry average. Industry-wide profitability also recovered, but not to pre-1977 levels. In contrast, the metal-mechanical sector as a whole exhibited deteriorating profitability as general expenses, such as insurance and other related costs, ate into profits.

TABLE 4.5

SHARES IN VALUE ADDED FOR SELECTED YEARS

(percent)

Industry Group/ Years	Labor Share	General Expenses		Remainder for Profits
		Total	Interest	
All Industry:				
1970	35.9	23.2	4.5	40.8
1977*	35.3	34.7	9.4	<30.0
1980	35.1	38.7	10.2	25.1
1986*	29.0	41.4	9.4	<29.5
Metal-Mechanical Sector:*				
1977	41.1	34.9	10.9	<24.0
1986	38.5	53.8	13.1	<7.7
Nonelectrical Machinery:*				
1977	49.5	35.9	9.3	<14.6
1986	39.1	37.0	9.3	<23.9

Labor share includes fringe benefits. The metal-mechanical sector comprises (ISIC Second Revision): metal products (381), nonelectrical machinery (382), electrical machinery (383), transport equipment (384), and scientific instruments (385).

Sources: Camilo, 1987, p. 172.; * denotes own calculations using data from DANE's *Anuario de Industria Manufacturera* for the cited years.

The employment trends presented in Table 4.6 show that higher employment explained the high labor share exhibited in nonelectrical machinery in 1977; the export boom prompted firms to hire workers and take advantage of falling real wages. In 1986 employment levels were once again on the upswing as the industry recovered from the second wave of the recession after having shed 16% (or 2700) of jobs. Real wages made only marginal gains and labor productivity posted a healthy increase. In 1977 they offered a compensation package close to the average for the metal-mechanical group, by 1986 this package was 18% below it, and 27% below the industry-wide average.

Despite the reduction in labor's share, employers and independent analysts, such as Wogart (1982) and the Chenery Employment Mission (1987), claim that labor costs, particularly the legislated non-wage component, represent a heavy burden. Wogart's estimates updated by Econometría (1989) show that the entire package of mandated fringe benefits as a proportion of wages rose from 41% in 1967 to 55% in the 1980s. In terms of the actual (as opposed to mandated) share of fringe benefits, they rose from 52% in 1977 to

83% in 1986 industrywide and 42% to 60% in the nonelectrical machinery subsector. According to Econometría (1989) industrywide increases were due to: (1) increases in social security contributions, (2) effects of inflation and payment of interest of *cesantías*, (3) increases in extralegal fringe benefits resulting from collective bargaining agreements, and (4) increases in severance costs during recession years.

TABLE 4.6

ANNUAL GROWTH RATES OF EMPLOYMENT, COMPENSATION, AND PRODUCTIVITY BETWEEN SURVEY YEARS: 1977 AND 1986

(percent)

Industry Group/	Average		Average		1977-1986	
Item	1975-76	1977	1984-85	1986	Average	s.d.
Employment (Remunerated workers):						
All Industry	2.4	3.6	-2.7	2.3	-0.2	3.0
Metal-mechanical	2.0	10.1	-2.4	1.2	-0.3	5.2
Nonelectric Machinery	0.7	10.0	-1.9	6.6	-0.6	6.4
Real Average Compensation (Including fringe benefits):						
All Industry	2.7	-5.7	3.5	0.2	3.0	5.8
Metal-mechanical	3.8	-12.1	0.8	-0.2	2.9	8.3
Nonelectric Machinery	0.9	-8.8	-2.7	0.8	2.9	25.1
Labor Productivity (Real output per remunerated worker):						
All Industry	-0.4	-3.8	10.6	6.3	4.1	4.8
Metal-mechanical	-2.0	-4.7	3.5	12.1	3.7	6.3
Nonelectric Machinery	-0.2	-8.2	-8.4	11.5	2.2	10.9

s.d.: standard deviation; Average compensation = (total compensation/number of remunerated workers). Metal-mechanical group includes metal products (381), nonelectric machinery (382), electrical machinery (383), transport equipment (384), and scientific instruments (385).

Data sources: Current peso figures from DANE's *Anuario de Industria Manufacturera* deflated with Banco de la República's *Revista del Banco de la República* wholesale price indices (see Table 4A.4 in Appendix C).

Econometría (1989), however, downplays the effect of legislated fringe benefits upon labor costs. They argue that employers make decisions based on total compensation, so that they trade off increases in fringe benefits against increases in basic wages. As evidence of this tendency they point to the fairly steady labor share in value added--33% over 1977-1986 with a standard deviation of only 0.6% for industry as a whole. For nonelectrical machinery as shown in Table 4.5, the labor share recorded greater fluctuation over the period; it peaked at almost 50% in 1977, fell to 30% in 1981 as average compensation plummeted and then settled to the period average at about 40%.

One way employers managed to reduce labor's share was through higher labor turnover to avoid benefits which accrue as a function of seniority, i.e., the *cesantía*. This may be the most serious effect of labor legislation--the ensuing losses in productivity from increased labor turnover. Available data at the national level shows greater turnover by the increase in the number of temporary workers.

Another important effect of labor legislation was emphasized by the Chenery Employment Mission (1987). The authors concluded that for smaller firms, the wider coverage of labor legislation meant the loss of cost advantages so important to their growth in the 1970s. Wider coverage is a function of inflation which has driven many small firms above the minimum asset value for which labor legislation applies. For smaller firms, the risks associated with a given worker are proportionately higher given the small employment base. Moreover, for those firms operating in competitive markets, these costs cannot be passed on to consumers. In contrast, in monopolistic industries, such as beverages and refineries, productivity increases reflect the ability of these firms to pass on higher costs to consumers.

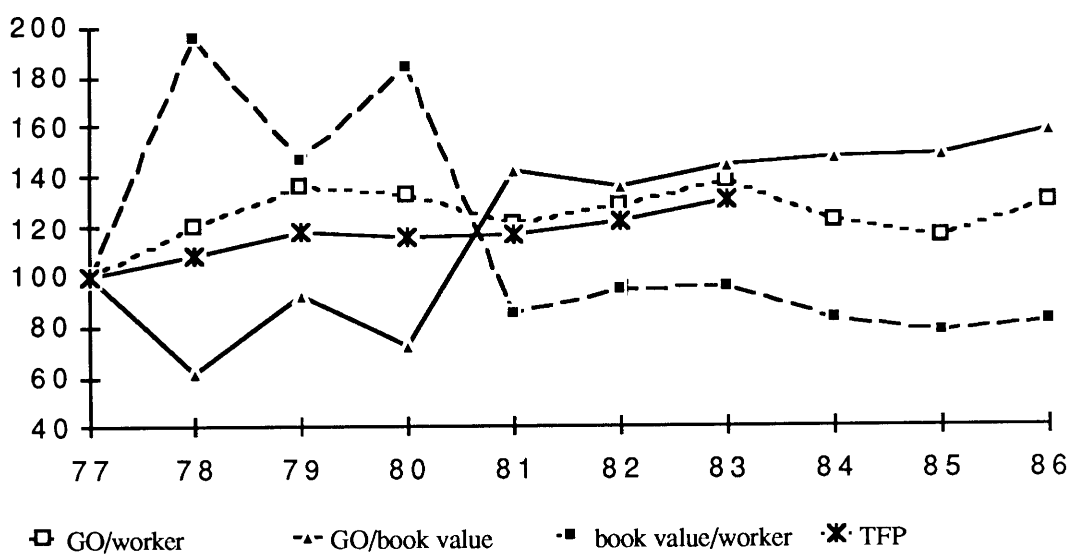
This may explain the modest labor productivity growth (2.2%; see Table 4.6 and Chart 4.2 below) in the nonelectrical machinery subsector, where industry concentration is low and smaller firms (employing fewer than 100 workers) predominate. Low concentration is supported by Robert's (1989) estimates of Herfindahl indices (sum of squares of plant market shares) showing nonelectrical machinery (ISIC 382) at about 33% to 40% of the industry average for 1977-1985. With respect to size, plants employing 100 or more employees made up less than 12% and 4% of all plants in this subsector in 1977 and 1986, respectively. In the first survey year, our firm interviews of agricultural equipment producers also showed a highly competitive market as smaller firms forced larger traditional producers out of the most productive agricultural region of Colombia--the Cauca Valley. These large producers, mainly located in urban industrial areas could not compete with the smaller firms located in this valley and offering lower prices and immediate servicing. By 1986 some firms, both large and small, had died and the industry was consolidating.

Improvements in TFP

In addition to showing declines in fixed capital, reductions in employment, and increases in the costs of production, we have shown that nonelectrical machinery was a fairly competitive subsector. Chart 4.2 below plots the levels of labor and capital

CHART 4.2

PRODUCTIVITY TRENDS FOR NONELECTRICAL MACHINERY: 1977-1986
(1977=100)



GO=real gross output; worker=number of remunerated workers; book value=real book value; TFP=total factor productivity. Data Sources: Current peso figures from DANE's *Anuario de Industria Manufacturera* deflated with Banco de la República's *Revista del Banco de la República* wholesale price indices (see Table 4A.4 in Appendix C); TFP estimates from Roberts (1989); see Chapter 2 for a discussion of the Tornqvist TFP index.

productivity, capital intensity, and TFP for the subsector. The latter estimates are taken from Roberts' (1989) TFP indices for 1977-1983 based on plant-level census data.[6] He

[6] Roberts (1989) the 3-digit ISIC deflator series from the central bank to determine real output. Labor is not corrected for hours worked. Material purchases are deflated using an industry-specific material price index. The capital stock figure is derived using the perpetual inventory method using 1977 stock as the base and differentiated by four types of capital assets: plant, machinery, transport equipment and land each with respective depreciation rates of 5%, 10%, 20% and 0%.

applies the Tornqvist index number formula described in Chapter 2 to series of output, number of workers, material purchases, and capital stock derived from perpetual inventory calculations.

The most dramatic trends are those related to fixed capital as measured by real book value, specifically the steep and lasting decline after 1980 noted earlier. The 1977-1980 period of trade liberalization facilitated an investment boom (set in motion by the coffee bonanza) that almost doubled capital-labor ratios in the subsector. The recession and trade restrictions (in response to the balance-of-payments crisis) brought stability such that capital intensity fell into the same pattern as labor productivity. TFP trends also followed labor productivity, but displayed a more steady improvement.

According to Roberts' (1989) TFP estimates, nonelectrical machinery producers stand out as the best and most steady performers within the metal-mechanical sector, registering negative TFP changes for only one year. In contrast, there was only one year of positive TFP growth industrywide, reflecting the high levels of capacity underutilization associated with the prolonged recession. For the seven-year period, nonelectric machinery producers averaged 5.1% TFP growth while industry as a whole averaged -2.4%.

With these estimates of TFP growth, data on entry and exit rates, import penetration and market shares, Roberts (1989) examines the impact on productivity of a movement away from the import liberalization begun in the late 1960s. Greater restrictions on imports were introduced in the first years of the 1980 decade to control balance-of-payments deficits. The authors posits that this policy shielded domestic producers from the salutary effects of import competition , thereby promoting the growth of small inefficient firms. Reduced competition allowed these marginal firms below the minimum efficient scale to survive. Comparing data from 1977-80 (increasing liberalization) and 1980-83 (decreasing liberalization), he offers as preliminary evidence of this hypothesis: (1) the increase in the number and proportion of plants with fewer than 50 employees and (2) the decline in size of entrants and their lower average market share. This evidence, Roberts argues, is consistent with the argument that trade restrictions allowed small inefficient producers to exist.

In this preliminary work, Roberts uses size differences as a proxy for efficiency, specifically the Herfindahl index (the sum of squares of plant market shares within an industry) measuring dispersion of plant sizes. Finding a skewed size distribution with few large and many small plants, he surmises differences in efficiency levels. However, the results of his regression models to explain TFP differences across industries point to the salutary impacts of import competition on the more highly concentrated industries , that is, those where market shares are concentrated among a few large producers. It seems then that without estimates of efficiency (not just proxies based on size), we might suggest that trade restrictions allowed large inefficient producers to exist and, moreover, be profitable as shown by Roberts data on profitability. In addition, from an examination of plant entry and exit, Roberts concludes that trade adjustment had little effect on exit or entry and suggests that the impact of import competition was exerted on continuing firms by dampening the average rate of growth of plants.

Our examination of aggregate data for nonelectrical machinery producers suggests that the death of presumably inefficient larger producers may help to explain productivity gains. In 1986 the number of larger firms (those with more than 100 employees) producing nonelectrical machinery was one-third of the 1977 figure. The survivors absorbed some of the labor released by firm deaths and/or contractions so that the average number of workers among larger firms jumped from 271 to 514, although as we noted overall employment fell by almost 2700. Capital-labor ratios (measured as real book value per worker) could not keep up, but these more labor-intensive survivors were more efficient in terms of real output per worker. In 1977 larger firm labor productivity was 50% greater than that of smaller firms, by 1986 they were twice as productive, although the differences in capital intensity between these size groups remained below 15%. These trends are only indicative since our data are aggregates of size groupings unlike Roberts' plant-level data. Nevertheless, these data show that the relationship between efficiency, size, and competition is complex and requires micro-level analyses to get an accurate reading of efficiency patterns within a particular industry.

CONCLUSIONS

Despite the early gains in productivity, the evidence suggests that the metal-mechanical sector has been plagued by stop-and-go trade policies, which have added uncertainty in both supply and demand. Colombian industrial evolution since the turn of the century has followed the coffee cycle; the level of aggregate demand is closely associated with coffee export earnings. During the upswing, coffee earnings are available to finance industrial imports and stimulate industrial production, while the downswings are characterized by tight import controls to relieve balance-of-payments deficits. Despite the liberalizing reforms implemented in the late 1960s, suspended in the early 1980s recession, and gradually reintroduced in the mid-80s, the structure of protection has not changed to fit Colombia's evolving industrial structure. Recurrent criticisms by contemporary analysts such as Ospina (1988) and the Central Bank (Coyuntura Económica, 1986) focus on the trade regime's: (1) continued relative protection of consumer goods sectors, (2) instability, (3) complexity, and (4) arbitrariness given the discretionary power in the hands of public officials charged with implementation.

In addition to the vagaries of the coffee cycle and the anachronistic structure of protection, producers have had to contend with the chaotic effects of financial regulation and deregulation. It is no wonder that Colombian analysts along with industry associations label the 1980s as a period of deindustrialization. Specifically, with respect to the metal-mechanical sector, they argue that the unstable macroeconomic climate together with a structure of protection still focused on consumer goods has placed in jeopardy the future technological development of the country.

We described broad trends in factor use, noting the stagnation of plant investment and the reductions in employment, labor share, and capital intensity. These data could provide initial evidence for deindustrialization arguments. Nonetheless, available TFP estimates for 1977-1983 suggest moderate productivity gains for nonelectrical machinery. We also presented preliminary evidence suggesting that their impact across sectors and firms may been differentiated by market structure, that is, plant size and market concentration. In the next chapter we examine these issues with plant survey data from agricultural and kitchen equipment producers. Specifically, we will examine how technical efficiency is related to size and factor use. Are smaller or larger firms more efficient with respect to total factor productivity (i.e., as measured by TEIs)? Did this pattern change between 1977 and 1986 when trade restrictions were increasing in relative terms? How did firms adjust to the more uncertain macroeconomic circumstances? Were reductions in labor and postponements in replacing capital equipment compensated elsewhere to provide for efficiency improvements and even technical progress?

CHAPTER 5

A DETERMINISTIC FRONTIER APPLICATION TO COLOMBIAN METAL-MECHANICAL FIRMS: 1977 AND 1986

In Chapter 2 we reviewed neoclassical models that attempt to decompose productivity change into improvements in the use of factors and the unexplained TFP residual we interpret as technical change. In addition to TFP refinements in terms of disaggregation, the measurement of capital, and adjustments for capacity underutilization, we explained in Chapter 3 how frontier methods further decompose the TFP residual by accounting for errors in optimization. Indeed, if markets were perfect and technology and information freely accessible, we would not need to worry about such errors. Prices would provide correct signals to direct the use of factors and informed or unmotivated managers would be replaced. However, our analysis in Chapter 4 of the context in which Colombian metal-mechanical firms operate suggests errors in optimization are likely to be very important. Even our limited review of frontier studies in Chapter 3 demonstrates that errors in optimization are important in Colombia, India , and the United States.

The purpose of efficiency and productivity measurement is simple. If we know what is wrong, we can target policies to mitigate the problem. However, with limited data, this diagnosis is not simple since there are three types of errors in optimization manifest at the firm level, and their origins lie in the interrelated technical characteristics of production--efficiency, bias, elasticity, scale, and homotheticity. Our empirical work focuses on technical inefficiency and uses technical efficiency indices (TEIs) to examine the other two types of errors--scale and allocative inefficiencies. As noted in Chapter 3, most frontier studies focus on the relationship between size and TEIs. Analysts basically test hypotheses concerning issues of scale--the existence of capital indivisibilities and/or economies of scale. Similarly, some frontier studies examine the relationship between factor proportions and TEIs to study allocative inefficiency. We go step further by analyzing the impact of distortions in product pricing and the other source of price or allocative inefficiency, capacity underutilization.

In this chapter we describe our empirical work using the deterministic production frontier on our sample of 50 firms initially surveyed initially by CBI in 1977 and revisited in 1986. Following the methods of Nishimizu and Page (1982) described in Chapter 3, we derive for our sample firms technical efficiency rankings for each survey year and then examine the issue of technical progress by looking at the efficiency improvements in the best-practice frontier across the survey years. After describing the key issues in our measurement of inputs and outputs, we turn to a discussion of the patterns of technical efficiency derived from our frontier calculations. In analyzing these results, we focus on two sets of hypotheses. The first set of hypotheses concerns substantive issues regarding firm performance and the second focuses on measurement issues. The former examine the evidence on the performance of this sample of Colombian firms to test long-debated arguments about the efficiency of firms in the context of inward oriented development strategies. Specifically, we look at three controversies regarding firm performance.

First, small firms are inefficient because they operate below the minimum efficient scale in limited markets, or, conversely, they are more efficient given their more appropriate factor proportions. Second, size and factor proportions are not systematically and directly related and, therefore, are not the central issues in efficiency. Rather the problems lie in managerial performance; entrepreneurs lack the technical and administrative know-how to efficiently organize production. Alternatively, protected markets do not provide entrepreneurs with the correct signal or incentives towards efficiency. Third, in order to survive recession and macroeconomic instability, firms curtailed efforts towards technical progress and focused on cost reduction. Alternatively, the argument that necessity is the mother of invention implies these efforts may have produced cumulative improvements which pushed out the best-practice frontier.

Unlike the comprehensive study underway by Roberts (1989), which we discussed in the previous chapter, we cannot hope to quantify the efficiency gains from greater market liberalization. Using the concepts of technical efficiency and its dynamic counterpart, technical progress, we can, however, illustrate how a nascent capital goods sector has responded to the opportunities and limitations presented by the ups and downs of the Colombian economy. In light of rapidly changing demand worldwide, recent literature on competitiveness and productivity has focused on firms' flexibility as key to their competitiveness and by extension their efficiency and productivity. For example, Sabel (1986), Hoffman (1989), and Alavi (1990) examine the implications of flexibility for developing country firms. They note somewhat optimistically that flexibility has long been a key to these firms' survival. We will study the issue of flexibility using our sample of firms by looking at the specific efforts of entrepreneurs in their attempts to survive recession and its tightening import controls.

The subject of our second set of hypotheses is an evaluation of alternative input measures, particularly the disaggregated capital services measure. If we cannot corroborate the patterns of efficiency indices, then we must question their usefulness much like those critics who labelled the TFP residual a measure of our ignorance. As we noted in the conclusion to Chapter 3, the literature is replete with methodological pieces, but most lack the corroborating data on specific entrepreneurial efforts that give concrete meaning to efficiency indices. Another aspect of this evaluation involves considering the potential bias from two important factors that tend to confound efficiency estimates--capacity underutilization and market power. As we noted in Chapter 2, not accounting for capacity underutilization biases the price of capital services upwards, while not recognizing market power biases the valuation of output downward for those firms who do not exert it.

Following this introduction, we justify our choice of the deterministic frontier for our small, but rich, set of Colombian data. Our measurement of inputs and outputs follows the basic notions of index number theory for aggregation in which weights reflect differing productivities. Our most significant contribution is the application of Mohr's (1986) disaggregated measure of capital services which takes into account vintage and type of asset. This is an important departure from standard practice where an aggregate estimate of total capital stock together with universal assumptions about vintage and depreciation are the basis of capital input measures. This not only violates the principles of aggregation by assuming all capital homogeneous, but ascribes universal qualities to capital without any notion of whether these assumptions are applicable or not in the specific context.

MODEL DEFINITION AND JUSTIFICATION

In Chapter 3 we explained the various techniques of efficiency measurement, indicating the requirements of each. Stochastic models offer the most theoretically appealing approach because they explicitly incorporate random error and offer the possibility of mitigating important deficiencies in data. These models include: (a) full-information maximum-likelihood estimation of a Cobb-Douglas production function with instrumental variables to derive average technical efficiency indices across industries to account for errors-in-variables problems, as in the work of Tybout (1988); (b) fixed-effects models using joint estimation of the share equations to get around the problem of insufficient degrees of freedom to derive firm-specific technical efficiency indices, as in the work of Seale (1989) described in Appendix B; and (3) variable-coefficients models to estimate a stochastic frontier from panel data allowing technical efficiency to vary across time as well as units and producing firm-specific indices of technical efficiency, as in the work of Cornwell, Sickles and Schmidt (1989).

Although our Colombian data is rich with qualitative and quantitative data on firm performance for the years 1977 and 1986, the sample is small covering 50 metalworking firms consisting of 30 firms producing agricultural implements and 20 firms producing industrial kitchens. This sample is a subset of the 1977 data gathered by Cortes, Berry, and Ishaq (CBI, 1985). For 1986 we conducted a follow-up survey to the CBI one, in which 27 of the 50 firms responded with the balance corresponding to 9 deaths and 7 non-responses. Moreover, we do not have complete price and quantity data on all inputs and outputs to be able estimate a fixed-effects model. We also consider the methods of Tybout (1989) inappropriate for our specific investigation where we are interested in the patterns of efficiency across firms rather than sectors economy-wide. Statistical frontiers do not offer significant advantages over deterministic ones. In addition to greater sample size demands, they require the analyst to make arbitrary judgements about the error distribution while still ignoring the random component of this error.

In Chapter 3 we enumerated the problems with deterministic frontiers: (1) its attribution of all deviation from the frontier to technical inefficiency, (2) its lack of tests for goodness of fit thereby precluding statistical inference, and (3) its sensitivity to outlier data. Despite these drawbacks, a comparison of frontier techniques by Corbo and de Melo (1986) suggests that the deterministic frontier yields similar rankings to those of stochastic methods. Moreover, we have tried to mitigate some of these problems. First, the deterministically derived technical inefficiency index can be considered an upper bound measure. Second, we recalculated the frontier without the most efficient firms in order to identify outliers and test the stability of the estimated frontier parameters. Most importantly, our technical efficiency indices were only one measure of firm performance. By analyzing how closely they were related to other measures, we evaluated their contribution towards a reasonable explanation of the main characteristics of the production process. Like those studies discussed in Chapter 3, we use multiple correlation techniques to examine the TEI patterns.

Our deterministic frontier model follows those described in Chapter 3. We assume that an upper-bound measure of a firm's inefficiency can be captured by the error term u. The linear programming problem we solved is based on a Cobb-Douglas production function (value added is a function of capital and labor inputs)

$$\ln VA^s = \alpha_o + \alpha_k \ln K + \alpha_l \ln L + u^s$$

where we minimize the sum of the deviations (over s firms) from the production frontier:

$$\min \Sigma_s u^s = (\underline{\alpha_o} + \underline{\alpha_k} \ln K + \underline{\alpha_l} \ln L - \ln VA^s)$$

subject to

$$\underline{\alpha_o} + \underline{\alpha_k} \ln K + \underline{\alpha_l} \ln L \geq \ln VA^s \text{ or } u^s \leq 0$$

$$\underline{\alpha_o}, \underline{\alpha_k}, \underline{\alpha_l} \geq 0$$

The error term is forced to be nonpositive, reflecting that actual firm output must be below or equal to potential or best practice output (denoted by the underlining). A measure of technical inefficiency for each firm is the antilog of the slack variable from the programming problem and by taking its reciprocal we derived the technical efficiency index (TEI). We estimated separate frontiers for each industry to assure comparability of production technologies and therefore the viability of the frontier as the appropriate standard of performance.

The Data and Input Measures

Our measurement of inputs and outputs follow basic index number theory in which aggregation is based on a weighting scheme using relative prices to reflect differing productivities. Because we were concerned with aggregation within (not across) a specific unit and for only two discrete time periods, we did not use the more complex index number formulae described in Chapter 2. Had we chosen a flexible specification of the production technology, such as the translog, in a time-series context we would have used its corresponding index-number formula, the Tornqvist-Theil discrete formulation. Given the richness of our data set on the input side, we disaggregated to six classes of labor, two types of fixed assets (machinery and buildings), and as many differing vintages of separate machinery as reported by the entrepreneur.

The Issue of Prices under Disequilibrium

As we noted in Chapter 2, Taylor (1979, p. 74) and Chenery (1983) have criticized TFP studies in developing countries. By the very nature of the structural transformation that justifies their classification, developing countries are in disequilibrium, which means that observed prices may not reflect true scarcity or relative productivities. Although Taylor's criticism focused on the problem of accurately capturing labor productivities in labor abundant economies through artificially controlled wages, the issue of whether prices accurately reflect relative scarcities is an important issue for the valuation of both inputs and outputs. While there is an ample literature on the determination of shadow prices in developing countries in the context of cost-benefit analyses, the issue of prices in TFP analyses has received little attention. Most TFP studies, such as that by Roberts (1989) for Colombia cited in Chapter 4, set aside this issue of prices. After deriving TFP estimates based on observed prices, Roberts (1989) examines the potential biases introduced by disequilibrium conditions. For example, he introduces the growth in sectoral demand as a variable to account for the problem of capacity underutilization during the early 1980s recession. He also examines profitability, market concentration, and import penetration to account for prevailing competitive conditions.

On the other hand, CBI in their micro level study focused on shadow prices, hoping to capture more accurately than previous studies the productivity differentials associated with relative resource scarcities. As they note, using shadow or near-shadow prices on the input side would require similar treatment on the output side, but the relevant data were unavailable and product prices were not too different. Considering the broad range of firms in the CBI sample, ranging from those with fewer than 10 employees to those with more than 100, we tried to examine the extent of product price differentials as well as these firms' attempts to differentiate their product through financing and distribution.

Unlike CBI, we chose to base our study of firms' relative performance on observed market prices and then compare these results to those derived under equilibrium conditions to see the magnitude of the bias presented by the divergence between market and shadow prices. Our use of market prices means for example, that the ability of firms to claim higher product prices while minimizing factor input costs (through positive organizational measures, knowledge of import controls and practice in filing loan applications, or through the exercise of privileged connections) will be reflected as higher TEIs. In effect, higher product prices not commensurate with quality differentials will be reflected incorrectly as higher technical efficiency. We used the real market rates for capital offered by differing financing sources--own, commercial bank, public bank, or supplier/moneylender. Accordingly, we used market prices for labor and output. Our main adjustment involved a thorough consistency check to assure these data presented a reasonable picture of firm production and finances for the survey years. We present the details of our input and output measures in the Technical Appendix.

For comparison, we explicitly corrected for two types of disequilibrium conditions: first, the existence of market power or a firm's ability to charge higher product prices for quality comparable to the competition, and second, capacity underutilization. Our sample data contain sufficient information with which to derive alternative TEIs under conditions of full capacity and price-quality comparability. In Chapter 2 we noted the preferred method to deal with the phenomenon of disequilibrium involves price adjustments. However, in the case of capacity underutilization, our data allowed only quantity adjustments. Specifically, we derived input and output estimates based on the estimated input-output characteristics of the firm at full capacity. In turn, these data form the basis for full-capacity TEIs. We asked entrepreneurs to estimate how much more output volume (in percentage terms) they could produce with their existing capital equipment and how many additional employees would be needed. We assumed that they would be able to sell (contract) their additional output (workers) at the same price (wages) as existing output (workers). We expected that if firms had been able to operate at full capacity, levels of efficiency for the sample would have been higher.

We took a similar approach to the issue of product price differentials. We asked entrepreneurs to compare their products' price and quality with that of the competition. On the basis of this comparison, we adjusted firm value added by the ratio of price over quality comparisons with the competition . For firms charging lower prices for comparable quality, this adjustment raised their value added by this ratio, in this case, greater than one. We verified the entrepreneur's evaluation by estimating the price-quality ratio using our own evaluation of firm quality with respect to competitors. This evaluation was based on a composite technical competence score based on on-site evaluations of the technical sophistication of the machinery, design and engineering capabilities, and organization of production.

Each of these three scores are composite scores based upon a number of criteria. The technical level considers completeness of machinery with respect to number of shops and processes as well as the sophistication of this machinery in terms of its degree of automation. The second score evaluates firm product design and engineering capability and refers to three criteria: product-design capacity rates firms' abilities in drafting and design to specification, engineering capacity rates their engineering/technical expertise in production, and the link between design and production attempts to capture the degree of coordination between demand, supply and production. The third score evaluates the firm on four aspects of plant organization: plant layout, capital maintenance, quality control, and pre-production planning.

Table 5.1 presents descriptive statistics for these three scores. They show some improvement over the years with continuing and significant differences by firm size as measured by the number of employees. The industry differences in the technical level lend further support to our estimation of separate frontier production functions. Although we will discuss these trends below, in terms of improvement over the survey years, the most significant is that related to design and engineering capabilities. This reflects an increasing professionalization of management and greater labor specialization.

TABLE 5.1

TECHNICAL COMPETENCE SCORES BY YEAR, INDUSTRY AND FIRM SIZE

Means and Standard Deviations (s.d.)

Year and Basis of Score	All Firms	Industry		Number of Employees		
		Agricult.	Kitchens	1-20	21-40	41+
1977:						
Technical level	6.7	7.6	5.4[a]	5.5	7.4	8.0[b]
(s.d.)	(2.5)	(2.4)	(2.2)	(2.5)	(2.0)	(2.4)
Design/Engineering	5.3	5.7	6.3	4.8	6.6	7.1[a]
(s.d.)	(1.5)	(1.6)	(1.4)	(1.0)	(1.3)	(1.3)
Plant Organization	7.3	7.5	7.1	5.9	8.0	8.1[b]
(s.d.)	(1.8)	(1.8)	(2.4)	(1.7)	(2.8)	(1.2)
1986:						
Technical level	7.6	8.9	6.2[a]	7.4	7.0	9.6[c]
(s.d.)	(2.3)	(1.3)	(2.4)	(2.6)	(2.2)	(1.1)
Design/Engineering	6.7[c]	6.5	6.9	5.3	7.0	8.6[a]
(s.d.)	(1.8)	(2.0)	(1.6)	(1.1)	(1.5)	(1.5)
Plant Organization	7.8	7.1	8.4	7.1	8.1	8.2
(s.d.)	(1.9)	(1.8)	(2.1)	(2.3)	(2.0)	(1.1)

Agricult.: agricultural implements; kitchens: kitchen equipment. Scores: Technical level: a maximum 11 point score reflecting:(1) completeness of the machinery, i.e., number of shops and processes (3 points), (2) sophistication of this machinery, i.e., manual to automated equipment (8 points); Design/Engineering: a maximum 11 point score for (1) product design capabilities (4 points); (2) production engineering capabilities (4 points), and (3) link between design and production (3 points); Plant organization: a maximum 12 point score (3 points each) for: (1) plant layout, (2) capital maintenance, (3) quality control and (4) pre-production planning. Means for given group (by year, industry and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level.

By comparing the TEIs under full capacity and price-quality adjustment against base case TEIs, we hoped to get an indication of the importance of these disequilibrium conditions. By examining TEI differences across firms operating at full capacity we hoped to distinguish between problems of low demand and recession from those of technical inefficiency. Similarly, we expected that if firms' prices reflect quality differences, we would be able to better distinguish technical efficiency from market power.

A Disaggregated Approach to Measuring Capital and Labor

Although at the micro level we skirt the issue of aggregation across production units, we still face the problems of unreliable data, particularly in the case of capital measures. It is in this area of input measurement where our work presents a departure from existing studies. The usual practice is to work from an aggregate estimate of the cost of replacement of the total capital stock and to annualize it into a capital flow or rental price, taking into account the years of useful life and the interest rate. Most studies assume a 15-to-25-year life and a real cost of capital between 8% to 12%--frequently used "guesstimates" in project evaluation studies. The CBI study attempted to estimate the service life parameter more accurately by considering actual life of new versus used machinery. Although they collected data on the interest rate offered in the capital markets depending upon the source of financing (real rates varied from 2% to 12% depending on the source--own, public or private bank, and supplier/moneylenders), as noted above, CBI used shadow prices for TEI calculations.

We chose to follow Mohr's (1986) vintage rental price of capital formula described in Chapter 2 and detailed in the Technical Appendix:

$$p_{vt} = q_{vt}\,(ATRR_{vt} + \delta_t)$$

subscripts v and t refer to the vintage and type of capital asset

where

q_{vt} = *asset price*
δ_t = *declining balance rate/ mean service life = 1.65/msl*
$ATRR_{vt}$ = *after tax real cost of capital* $= r_{vt} - \pi_{vt}$
r_{vt} = *nominal after tax cost of capital*
π_{vt} = *wholesale price index for the output produced with the asset*

This formula looks deceptively simple, however, each element is a weighted average of the individual capital assets. Instead of a straight sum of the cost of the total capital stock used in most studies, the characteristics of each individual element of the capital stock (i.e., its price, service life, financing cost) are taken into account. In effect, the straight sum or aggregate measure assumes all capital is homogeneous. The disaggregated approach suggested by Mohr weighs each element in accordance with index number theory to account for differences in vintage for each type of asset that we would expect to affect that asset's productivity. We identified two types of capital assets, machinery and buildings, each requiring alternative assumptions about depreciation.

For a given type of capital asset, the formula for r_{vt} is a weighted sum of the net capital stock (in place in the base year chosen as 1970 and still in service in the current or survey year) plus each year's stream of capital investments where the weights are the real after tax cost of funds at the time of purchase ($ATRR_{v\tau}$ or $r_{v\tau} - \pi_{v\tau}$ where τ refers to year of purchase; see equation A.1 in the Technical Appendix). The formula assures that all costs of capital are decayed through the weighting scheme in which the importance of each vintage's cost of capital decreases with age. This avoids the familiar problem of charging historical capital unreasonable current rates; the recent cost of capital is more important in determining the firm's overall opportunity cost of capital.

Using our estimates of mean service life and mean years in use or vintage, we also derived the usual capital-input measure based on estimates of the aggregate capital stock. This information, we expect, substantially improved these estimates. Rather than assume universal parameters regarding depreciation we used those specific to the firm and the sector. We applied an often-used formula for annualizing the capital stock into its flow or rental price

$$p_K = \frac{rK^d}{1-(1+r)^{-n}}$$

where r = *real interest rate* = $r - \pi^e$

n = *service life*

$K^d = K(1-\delta)^v$

K = *asset price*

δ = *depreciation* = *1.65/mean service life*

v = *years in use*

A question of interest in this research is whether the more complex disaggregated measure of capital yields different and more reliable results than unweighted or aggregate measures. The zero-order partial correlation coefficient for 1977 is 89% (and significant at the .001 level) reflecting the common assumptions with respect to depreciation parameters. As we move away from the base year, the different treatment of changes to the capital stock and inflation reduce this correlation to 77% for 1986.

We also estimated two measures of labor to test the robustness of results. In addition to total labor days for each of the survey years, we measured labor in efficiency units or wage-weighted unskilled equivalent labor days. These two labor measures were highly correlated at 86% (.001 significance level). By using basic daily wage rates as weights (not including fringe benefits), which vary according to skill types, we expected to pick up productivity differences related to the different skill mix across firms. Given the decline and stagnation in real wages since 1977 due to inflation (noted in the previous chapter), CBI (1985) and Econometría (1989) regard that wage rates tended to follow real productivity trends.

Specifying Production Characteristics

In addition to providing detailed information about the number and cost of different categories of labor (managerial, administrative, technical, skilled, and unskilled) and capital assets, these data provide insights in two other areas where there is seldom information. First, our sample data provide a rather full description of the production process. They allow us to quantify: the share of output produced on a unit-by-unit basis (as opposed to production in batches or lots, or in series); the share attributed to the main product (a measure of product specialization); the share represented by intermediate purchases; and the share of output/inputs sold to/bought from other firms.

These production characteristics can capture a full range of production operations. For example, at one extreme we find smaller firms whose production is on a unit-by-unit basis--often referred to as a discontinuous production process. As orders come in, workers, organized with a low degree of task specialization, collaborate to produce the given product until the next order is solicited. Product specialization may be low, imposing the costs of diseconomies of scale and scope. The share of intermediates may be high, reflecting a simple technology focusing largely on assembly. Accordingly, given the low volume, but relatively diverse types of output, the firm probably does not participate in either subcontracting for or to other firms, instead relying on direct consumer and intermediate purchases. Some of these attributes were noted by Katz (1980, 1982) in his characterization of the Latin American metal-mechanical sector, and more generally, by Chudnovsky and Nagao (1983) in their review of capital goods production in developing countries.

Second, we have a number of variables to describe the financial characteristics of firms. We calculated an often-used measure of profitability, the price-cost margin (PCM)--the excess revenues after covering variable costs. As Roberts (1989, p.23) notes, the PCM reflects plant profits and payments to fixed factors, i.e., capital, so that "each plant's PCM varies with the level of profits earned given demand conditions, plant efficiency, and output market competition as well as a plant's capital intensity." As CBI (1987) confirmed, we would also expect technical efficiency to be an important determinant of profitability. Only in the case of highly noncompetitive and distorted markets, would we expect firm efficiency not to be correlated with profitability. In addition, profitability is also influenced by a variety of financial characteristics. Some of these include the real cost of capital ($ATTR_{vt}$ above), the share of materials purchased on credit, the share of sales made on credit, and the ratios of the stock of materials and finished products to sales. Again, in the case of smaller firms, we expected these shares to be relatively low reflecting their greater difficulty in obtaining credit for both fixed and working capital. Because of the small amounts of credit, transactions costs for small firm borrowers are proportionately higher than for large firms.

Patterns of Technical Efficiency

In this section we describe the patterns of technical efficiency resulting from the data and calculations discussed above. As noted in the introduction to this chapter, we will examine three long-debated controversies: (1) the relationship between size, technical efficiency and factor proportions, (2) the importance of managerial know-how to production efficiency, and (3) the viability of the concept of technological progress in developing countries. We will treat the first two issues in this section and discuss technical progress in the next section.

Size, Technical Efficiency, and Factor Proportions

Most studies on the efficiency of manufacturing in developing countries focus on firm size differences. One group tests the argument that the inward orientation of developing countries encourages the growth of firms below minimum efficient scale. For example, ongoing studies by Tybout et al. (1989) for Chile and Roberts (1989) for Colombia using total factor productivity estimates (to trace efficiency improvements through time) and production function estimation (to look specifically at the returns-to-scale parameters) provide some support to this argument.

On the other hand, studies by Page (1984) and CBI (1987) compare firm-level efficiency rankings to test the argument that smaller firms are efficient producers. In comparison to large firms, small-is-beautiful advocates claim that smaller firms make use of abundant labor supplies while saving on scarce capital. Although recognizing that size can be measured by value of assets or sales, these studies use number of employees as a proxy of firm size. As described in Chapter 3, Page (1984) finds that larger firms tend to be more efficient and suggests that plant-scale economies operate in sophisticated metal-mechanical industries such as machine tools. These findings are based on pairwise analysis of variance of TEI rankings between the small firm group and other size classes. CBI do not find a similar systematic relationship between size and TEIs, but concede that capital indivisibilities may explain high capital-output ratios for small firms in their metal-mechanical sample. In the discussion below, we will first examine the relationship between size and technical efficiency and then turn to the related issue of capital intensity.

The Relationship Between Size and TEIs

Table 5.2 presents our TEI results classified by year, industry, and firm size, as measured by number of employees. We find no statistically significant differences across size groups regardless of capital measure used (Table 5A.1 in Appendix C confirms this result in the case of the aggregate or unweighted labor measure). As noted above, CBI (1987) also report a lack of association between size and technical efficiency for their 65 firm metalworking sample. However, Table 5.2 demonstrates that this is not the case when we isolate the two industries (agricultural implements and industrial kitchen equipment) common to our sample. CBI's TEIs for our common subsample show larger firms as a group were significantly more efficient than smaller firms.

Our TEI data confirm that larger firms were able to maximize output to about 64% of best practice. This compares with the sample average of about 56% to 58% of best - practice output for 1977, with the more optimistic appraisal derived from our disaggregated capital measure. This level of samplewide average efficiency is higher than comparable estimates by CBI, although Spearman rank correlation coefficients of 62% and 66% (at the .001 level of significance) show that CBI's and our TEIs are highly correlated. The differences between our TEIs and those estimated by CBI are most evident in the case of small firms; our TEIs portray a more efficient group on average. This reflects differing measurement methodologies.

TABLE 5.2

TECHNICAL EFFICIENCY INDICES (TEI) BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in percentages with respect to the best-practice frontier

Year/ TEI Measured with	All Firms	Industry		Number of Employees		
		Agricult.	Kitchens	1-20	21-40	41+
1977:						
p_K-LUE	56	63	46^b	56	48	64
(s.d.)	(28)	(24)	(31)	(31)	(27)	(21)
p_{vt}-LUE	58	64	49^c	55	54	65
(s.d.)	(28)	(24)	(32)	(34)	(23)	(23)
CBI's p_K-LUE	51	57	40^b	41	53	64^c
(s.d.)	(28)	(28)	(26)	(24)	(26)	(33)
1986 (current pesos):						
p_K-LUE	64	61	65^y	73	55	64
(s.d.)	(25)	(30)	(18)	(25)	(23)	(27)
p_{vt}-LUE	63	61	64^z	66	60	60
(s.d.)	(24)	(28)	(19)	(23)	(23)	(23)
1986 (constant pesos):						
p_K-LUE	58	60	52	59	54	67
(s.d.)	(24)	(26)	(22)	(25)	(24)	(28)
p_{vt}-LUE	58	59	56	60	53	65
(s.d.)	(24)	(26)	(22)	(26)	(22)	(29)

Agricult.: agricultural implements; Kitchens: kitchen equipment; p_K: aggregate measure of capital flow; LUE: labor in unskilled equivalent person days; p_{vt}: disaggregated measure of capital services; CBI's TEI estimates refer to those in Cortes, Berry and Ishaq (1985; printouts) based on 46 of the 50 firms common to both samples. Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level. Means by industry by year are significantly different at the: y= .01 level; z= .1 level.

One possible explanation is that CBI's estimate of the rental price of capital included working capital (measured as the sum of material and finished product inventories) and ours did not. Nevertheless, and despite sample differences, Table 5A.2 in Appendix C shows that our aggregate capital measure is only about 10% higher on average than CBI's. The lower variance for our figures reflects a much more uniform sample having excluded 15 firms producing a variety of pumping/irrigation equipment and diverse agricultural capital goods. CBI did not make use of the asset-specific information regarding vintage and service life given their reliance on the traditional unweighted formula for annualizing capital stock estimates.[1] In light of the positive relationship between firm size and working capital demonstrated by CBI (1987, p.117), we expected that exclusion of working capital from our TEI calculations would favor larger firms. Comparison with CBI results suggests this was not the case.

An alternative explanation for the different patterns in our and CBI's TEIs lies in the calculation of the deterministic frontier whose main weakness is its reliance on a subset of the observations. CBI do not report attempts to de-sensitize the frontier. This involves re-estimating the frontier without the most efficient observations until parameter estimates stabilize. We considered this an important step in light of the broad range of firms in the sample; the more diverse the sample, the greater the problem of outlier data biasing the frontier. By de-sensitizing the frontier, we seemed to have reduced the bias favoring the largest firms. From the original CBI sample, we excluded a group of producers of varied agricultural capital goods, mostly pumps and post-harvest equipment, thereby maintaining a more homogeneous subsample.

TEI differences across the two industries fall in line with expected patterns. For example, Table 5.2 shows that in 1977 kitchen equipment firms were busy meeting the demand of the construction boom. Demand was strong and allowed this group to produce on average less than half of best-practice output. As noted in Chapter 4, this demand was fueling by channelling credit to housing; as a share of total institutional credit outstanding, the construction sector claimed 27% of funds compared to 20% and 25% for agriculture and manufacturing, respectively. Agricultural equipment producers, on the other hand, were engaged in a competitive race as some of the largest and oldest firms located in the industrial cities lost markets to smaller firms located in the richest agricultural areas.

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[1] CBI do not explain their assumptions on depreciation, and according to the formula they provide (CBI, 1987, p. 241) depreciation is not incorporated into their rental price of capital calculations. We should also note that our labor estimate is about 18% lower, although our measurement methodology differed only marginally from CBI's.

By 1986, the average efficiency of surviving firms increased to over 60% of best-practice output, although the patterns across industry and firm sizes vary depending on whether measures are in current or constant pesos. Agricultural equipment producers slipped slightly compared to the marked gains of kitchen producers. This is unexpected considering that competition was keener in the former and the recession had a more devastating impact in clearing out marginal firms (as described below). Nevertheless, the gains in technical efficiency are corroborated by our evaluation of their technical competence, specifically their organization of production. Table 5.1 shows that in terms of plant organization, kitchen equipment firms registered greater gains . It appears that while agricultural equipment producers focused on improving their capital equipment, as shown by their technical level, kitchen equipment firms concentrated on improving plant organization.

Survivors vs. Nonsurvivors

In Chapter 4 we described difficult economic conditions of the intervening period between survey years. In 1977 firms had to fight hyperinflation. By 1986 hyperinflation had not subsided, but firms had to face two additional challenges--the recession and stricter control on traded inputs. It is no wonder that one-fifth of the original firm sample died in this intervening period. These deaths were attributed mostly to plummeting demand in the two waves of the recession. Not surprisingly, given the disarray in the financial sector, the next most important reason was problems with debt. In addition to firm deaths, nonsurvivors included 8 firms (16%) which ceased production and turned to repair and retail activities. In terms of timing, firm deaths coincided with the first trough of the recession beginning in 1981; firms performing marginally in 1977 were too weak to survive.

An examination of death rates by industry shows that agricultural implements firms were most severely affected. Whereas only one of the original 20 kitchen equipment firms died (a death rate of 5%), 9 of 30 or 30% of agricultural implements firms failed. This is in line with overall industry trends as demonstrated by comparing 1977 and 1986 gross output levels for the respective 4-digit ISIC aggregates. In agricultural machinery (ISIC 3822), real 1986 gross output was about one-half that registered in 1977. In kitchen equipment (ISIC 3824,3829 and 3812), real 1986 gross output was 70% to 80% of 1977 levels depending on whether we use our implicit industry deflators or those published by the Central Bank (see Technical Appendix and its Table A.3).

Our review of aggregate census data in Chapter 4 suggested that larger firms in nonelectrical machinery appeared to have sustained heavy losses during the 1980s recession; however, from our sample data, we find that survival was not systematically related to firm size. Examining the differences between survivors and nonsurvivors, we found nonsurvivors were less than half as productive in their use of capital and labor, and their sales and value added averaged 45% and 38% that of survivors in 1977. On average, surviving firms also had: a more stable labor force (mean years of production workers' experience with the firm), a more experienced entrepreneur (years of experience in production/administration), a higher ratio of skilled workers, a later vintage capital stock, higher technical competence scores, and higher TEIs. These differences, however, were not statistically significant.

Table 5.3 shows statistically significant differences between survivors and nonsurvivors in 1977 according to two definitions of survival--survival in production and survival in the industry. Even by the more stringent definition of survival in the industry, single-factor productivity ratios for both capital and labor measures would have been good predictors of firm survival into 1986.

TABLE 5.3

DIFFERENCE OF MEANS TESTS BETWEEN SURVIVORS AND NONSURVIVORS: 1977 SINGLE-FACTOR PRODUCTIVITY MEASURES

Means and Standard Deviations (s.d.) in thousands of current pesos

Item compared across groups:	Survival in Production		Survival in Industry	
	Survivors	Nonsurvivors	Survivors	Nonsurvivors
VA/p_K	15.8	8.8[b]	17.9	7.5[a]
(s.d.)	(15.2)	(5.1)	(15.9)	(4.4)
VA/p_{vt}	10.6	6.0[b]	12.3	4.7[a]
(s.d.)	(10.9)	(4.2)	(11.3)	(3.6)
VA/LUE	0.2	0.2[b]	0.3	0.1[a]
(s.d.)	(0.2)	(0.1)	(0.2)	(0.1)
VA/LPD	0.5	0.3[b]	0.5	0.3[a]
(s.d.)	(0.3)	(0.1)	(0.3)	(0.1)

VA: Value added; p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LUE: labor in unskilled equivalent person days; LPD: labor in person days. Means of respective groups (by definition of survival) are significantly different at the: a= .001 level; b= .01 level; c= .1 level.

Under the definition of survival in the industry, some TEIs registered significant differences of means. This failure of our 1977 TEIs to predict survival consistently into 1986 reflects the reality that technical efficiency is but one aspect of firm performance. For example, the TEI based on the disaggregated capital measure (p_{vt}) and labor in unweighted person days (LPD) showed survivors were 15% more efficient in 1977 than nonsurvivors who averaged about 40% of the best-practice output. TEI results for the full-capacity and quality-adjusted scenarios suggest that nonsurvivors had more fundamental problems than those related to underutilized capacity or the lack of market power to charge prices commensurate with their product quality. Even under full capacity and output market conditions, nonsurvivors were less efficient than survivors in 1977. We turn first to the issue of size and capital intensity and then to their relationship with other production characteristics to sort out these other factors.

Size and Factor Proportions: Capital Indivisibilities

Our TEIs for both 1977 and 1986 show medium-scale firms tend to have the lowest levels of technical efficiency of all size groupings. This difference, however, is much less pronounced for TEIs based on the disaggregated capital measure (p_{vt}-LUE in Table 5.2).

On the basis of TEIs and capital-labor ratios, presented in Tables 5.2 above and 5A.3 in Appendix C, we find no support for the argument that small firms tend to be labor intensive and large ones capital intensive. For 1977 medium-scale firms are both the most capital-intensive and least-efficient size group. By 1986 small firms show the highest capital intensity yet they also tend to be very efficient. These data also show that larger firms spread their capital over a larger number of workers so that, in fact, these firms cannot be considered capital intensive.[2] Apparently, technical efficiency is consistent with a full range of capital-labor ratios. Echoing the findings by Little, Mazumdar and Page (1987), our comparison of capital-labor ratios between survivors and nonsurvivors provides no support for the argument that inappropriate factor proportions were linked to poor performance. Regardless of the capital or labor measures used, differences in capital intensity between survivors and nonsurvivors were slight; we could not reject the null hypothesis of no difference between these groups.

Although CBI capital measures differ, they also conclude that small firms have high capital-labor ratios providing evidence for the existence of capital indivisibilities. They note that this pattern of capital intensity is related to firm growth; in the face of capital indivisibilities firms grow into their equipment gradually adding more workers and thereby lowering their capital-labor ratios (see Table 5A.3 in Appendix C). Our most capital-intensive size group in 1977, medium-scale firms, were younger. By 1986, however, the relationship between size, age, and capital intensity appears to have been disrupted by the early 1980s recession and its contingent reductions in employment. The most capital-intensive group in this later year, small firms, tended to be older with more experienced entrepreneurs and older vintage capital equipment (see Table 5A.4 in Appendix C).

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[2] CBI (1987, p.117) data on capital-labor ratios (measured as the total stock (not service flow) of fixed capital per unskilled equivalent person day) show that medium scale firms have the lowest capital intensity, followed by small firms, and that large firms are the most capital intensive. Even when we derived comparable capital stock to labor ratios we confirmed the pattern we report above in the text.

Size, Factor Proportions, and Other Production Characteristics

The production data in Table 5A.5 in Appendix C provide further signals as to the reason behind the capital intensity of medium-scale firms in 1977. Compared to other size groups, they had higher levels of primary product specialization, a higher degree of vertical integration (as signalled by the low intermediates share or alternatively a higher share of value added), together with a higher share of subcontracted output for other firms. Taking advantage of the high growth economy of the late 1970s, these firms invested in capital equipment. In order to maximize its use, they sought greater specialization and forward linkages. In contrast, the largest firms, which tended to be the oldest both in terms of firm age and capital vintage, registered the lowest capital-labor ratios, while producing a wider range of products (mostly in batches or in series versus unit-by-unit) and subcontracting inputs from other firms (see Table 5A.5 in Appendix C). Given their substantial capacity, larger firms took advantage of this period of high growth to increase capacity utilization through product diversification and some exporting as a way to break the limitations of domestic market.

By 1986, after the recession took its toll, some of the capital-intensive medium-scale firms had lost employment and thus fell to the ranks of small firms, making this the more capital-intensive size group. To exploit their capital equipment, they increased their subcontracting to other firms. Surviving large firms also lost employment, but found they had to renovate a portion of their capital stock (as shown by the later vintage of capital of this size group for 1986), move toward greater primary product specialization, and reduce the share of intermediates as well as subcontracted inputs. This differential response to sagging demand by firm size mirrors similar behavior noted by Scott (1983) in his study of subcontracting linkages in the US garment industry; large firms tend to contract linkages while small firms increase them to survive.

The statistically significant differences between survivors and nonsurvivors are presented in Table 5.4. These differences support the trends noted above. The death of three large agricultural implements firms in the sample showed their failure to adjust their organization of production to lagging demand; nonsurvivors' share of unit-by-unit production was one-third that of survivors. More than firm size, we find that age of the firm and the institutional learning this represented was important; nonsurvivors tended to be younger. However, regardless of the definition of survival, nonsurvivors stand out for their dependence on customer orders and lower profitability. This reliance on orders reflected a shortage of working capital. Moreover, nonsurvivors also had greater dependence on intermediate purchases yet a lower share of these purchased on credit than survivors. In terms of profitability, given that our PCM is based on value added, lower profitability equates with a higher labor share--the product not distributed to labor goes to profits.

As we noted in the previous chapter, an important trend in nonelectrical machinery was the reduction in labor's share. It appears that nonsurvivors' failure to follow these sectoral trends was a factor in their demise. In 1977, a time of high aggregate demand, almost three-quarters of entrepreneurs noted a problem with the cost of labor, while almost half cited problems with labor tractability, such as union demands or threats of labor unionization. By 1986 the recession had eased labor demands. For that year, less than a third of surviving firms reported labor cost problems. The slack economy of this latter period reduced the share of those reporting any kind of labor problems to less than one-quarter from 90% in 1977. At the same time, shorter-term contracting as the predominant type of labor contract increased from 28% to 39% of the sample. This was an effective means of reducing labor costs; those with shorter-term contracting registered significantly lower wage bills and fringe benefits.

TABLE 5.4

DIFFERENCE OF MEANS TESTS BETWEEN SURVIVORS AND NONSURVIVORS: 1977 FIRM CHARACTERISTICS

Means and Standard Deviations (s.d.) in percentages unless otherwise noted

Item compared across groups:	Survival in Production		Survival in Industry	
	Survivors	Nonsurvivors	Survivors	Nonsurvivors
Unit-by-unit Production	31	11[c]	28	26
(s.d.)	(39)	(31)	(37)	(42)
Intermediates Share	43	54[b]	43	49
(s.d.)	(14)	(12)	(13)	(14)
Sales by Order	56	80[c]	52	78[b]
(s.d.)	(42)	(34)	(43)	(32)
Materials on Credit	59	22[b]	57	41
(s.d.)	(37)	(41)	(38)	(45)
Price Cost Margin	61	51[c]	64	50[b]
(s.d.)	(21)	(19)	(21)	(18)
$ATRR_{vt}$	6	4[c]	5	5
(s.d.)	(3)	(3)	(3)	(3)
Firm age (years)	15	10[c]	15	13
(s.d.)	(11)	(7)	(12)	(9)
Labor Share of VA	39	49[c]	36	50[b]
(s.d.)	(21)	(19)	(21)	(18)
Capacity Utilization	81	66[c]	84	67[b]
(s.d.)	(21)	(27)	(21)	(23)

The first three items are expressed as a percentage of output; Price Cost Margin=(Value added-Total wage bill)/Value added; VA- Value added; $ATRR_{vt}$: after tax real cost of capital; capacity utilization=(actual value added/full capacity value added). Means of respective groups (by definition of survival) are significantly different at the:a= .001 level; b= .01 level; c= .1 level.

Without complete quantity data on output as well as inputs to examine allocative or price efficiency, we cannot definitively say whether small firms were overcapitalized. Although technical efficiency tells us whether firms maximize output (i.e., are located on the production surface), allocative efficiency verifies whether they use the cost-minimizing mix of inputs (i.e., are located on the point of tangency with the isocost line defining the trade-off between factors). Comparison of the after tax real cost of capital ($ATTR_{vt}$; see Table 5.6) suggests that large firms had higher costs, but we cannot claim that smaller more capital intensive firms were encouraged to overcapitalize because of relatively cheap capital. The evidence from Table 5.4 suggests that nonsurvivors' lower rates may have initially made marginal investments feasible. However, the recession proved a more rigorous test, lending some support to those opposing preferential credit whose low rates make even marginal investments appear feasible.

We tried to examine differences in capital intensity using multiple correlation techniques. Table 5A. 6 in Appendix C presents the results of the estimated regression models. The results are poor especially for 1977, but they tend to complement the patterns we noted above. In the case of the capital-labor ratio based on the disaggregated capital measure (p_{vt}), size contributed to the explanatory power of the model, but its coefficient was not statistically significant and the magnitude of the impact of size on capital intensity minor. Other variables related to the organization of production and the capital-labor trade-off were more important. For example, in line with expectations, the higher the share of unit-by-unit production, the lower the capital intensity. Labor costs were also important. Those entrepreneurs reporting labor cost as a problem did opt for more capital, and the coefficient for the skill ratio variable suggests they tended to substitute capital for skilled labor.

This complementarity of capital and unskilled labor echoes the findings by Little, Page, and Mazumdar (1987, p. 170) discussed in Chapter 3. As these authors point out, these findings are incompatible with recent empirical work based on aggregate manufacturing sector production functions in LDCs. Rather they support historical studies of productivity differentials between the United States and England demonstrating a higher elasticity of substitution between capital and skilled than unskilled labor. Given the United States' relative scarcity of skilled workers, it enjoyed a faster rate of capital deepening than England. For 1977, 75% of entrepreneurs complained about the availability of skilled workers. The most important determinant of capital intensity for both capital measures, however, was the share of input costs subcontracted from other firms. As expected, the greater the dependence upon the production of third parties, the lower the firm's capital intensity.

A surprising result from our attempts to explain the variation in 1977 capital intensity is the positive impact of capital costs. Indeed, the three most efficient kitchen equipment producers had high capital costs and high capital-labor ratios in relative terms. As a result, they registered high labor productivity and in general paid higher wages for skilled workers (though comparable wages for unskilled) than other firms. These same patterns hold when comparing all kitchen equipment producers with those in agricultural implements. Moreover, these patterns do not suggest that capital-intensive firms were using inappropriate factor proportions implying a problem of allocative inefficiency. Differences in factor prices were not significant.

For 1986 differences in factor prices were smaller than in 1977. The results from the 1986 regression model reflect different considerations in the capital labor trade-off. As noted above, the focus shifted away from labor to material inputs and capacity utilization. Following our three kitchen equipment makers cited as most efficient in 1977, these firms added employees thereby reducing their capital intensity. However, they continued to define the best-practice frontier because of their ability to keep capacity utilization above and materials inventory below the average.

These relationships and trends are confirmed from our analysis of the determinants of technical efficiency. We estimated separate regression models for each survey year to account for variations in slope, which were apparent in the matrix of correlation coefficients and confirmed by the poor performance (F test results) of the model pooling data for both 1977 and 1986. Even a cursory look at the different conditions between survey years and the changes in the surviving firms during this period would suggest pooling to be inappropriate. Table 5.5 presents the best fit derived from our modelling efforts.

TABLE 5.5

REGRESSION RESULTS: DETERMINANTS OF TECHNICAL EFFICIENCY

Standard Errors in parentheses

Independent Variables	Ln TEI as dependent variable measured with LUE and: 1977		1986		1986 (1977$P)	
	p_k	p_{vt}	p_k	p_{vt}	p_k	p_{vt}
Constant	0.14	0.17	-2.14[a]	0.30	-3.04[a]	-3.00[a]
	(0.59)	(0.61)	(0.55)	(0.51)	(0.70)	(0.64)
D-industry dummy	0.28	0.35[c]		-0.18		
(agriculture=1)	(0.17)	(0.18)		(0.13)		
Intermediates share	-2.20[a]	-2.96[a]				
(% of output)	(0.64)	(0.67)				
Unit-by-unit prdtn.	-0.67[b]	-1.04[a]				
(% of output)	(0.22)	(0.24)				
CEO experience	0.23[c]	0.31[b]				
(ln of years)	(0.12)	(0.13)				
Skill Ratio				-0.53		
(% skilled in prdtn)				(0.35)		
University dummy	0.37[b]	0.32[c]				
(attendance=1)	(0.19)	(0.19)				
Vintage of capital			0.45[b]	0.16	0.39[b]	0.35[b]
(ln of years)			(0.17)	(0.18)	(0.15)	(0.15)
Technical level					0.86[b]	0.81[b]
(% of top score)					(0.34)	(0.33)
Plant organization	-0.67	-0.88c	0.98b		0.65[c]	0.56
(% of top score)	(0.52)	(0.54)	(0.43)		(0.40)	(0.40)
Subcontracting	-1.31[c]	-1.29[c]				
(% of output)	(0.73)	(0.76)				
Capital labor ratio					-0.21[c]	-0.24[b]
(ln pesos/worker)					(0.12)	(0.09)
Materials Stock			-1.24[b]	-1.30[b]	-1.54[b]	-1.29[b]
(% of sales)			(0.52)	(0.49)	(0.49)	(0.49)
R^2 adjusted	0.52	0.64	0.47	0.31	0.52	0.54
N (observations)	34	34	23	26	23	23
F	6.16[a]	9.40[a]	7.54[a]	3.87[b]	5.81[a]	6.15[a]

1977$P- constant 1977 pesos; Ln: natural logarithm; Agriculture: agricultural implements; p_k: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LUE: labor in unskilled equivalent person days; Regression coefficients are significant at the: a= .001 level; b= .01 level; c= .1 level.

For 1977 we find that in the presence of other variables describing specific production characteristics, neither firm size nor factor proportions were important in explaining firm variations in technical efficiency. The most important variables, all exerting a negative effect on technical efficiency, were the share of intermediates (that reduced the firm's value added), of unit-by-unit production (that reduced savings from even limited labor specialization and imposed diseconomies of scope), and of output sold to other firms (that exerted a similar and limiting effect as reliance upon orders in a time of high demand).[3] The disadvantage of the discontinuous production process in both years is clear from a comparison of the most and least technically efficient firms. The least efficient produced almost the entirety of their output on a unit-by-unit basis. This translates into a much higher labor share even with equal capital intensity.

For 1986 we can also conclude that firm size appears to have little impact on technical efficiency. However, we found that for our constant peso (1977$P) models, capital intensity, in part reflecting underutilized capacity, worked against technical efficiency although with minor impact; a ten percent increase in the capital-labor ratio was associated with a 2% decline in technical efficiency. Confirming our earlier findings regarding the increasing difficulties in obtaining material inputs, the results for both capital measures, deflated and in current pesos, show that the share of materials in stock exerted the greatest negative effect on technical efficiency. As import controls tightened relative to 1977, firms significantly increased their material inventories (see Table 5A.7 in Appendix C), and this reduced the efficiency of production. In 1977, half of the firms reported material inputs problems; by 1986, two-thirds claimed this to be a serious difficulty, although most found there was little they could do to mitigate the problem.

In terms of the increasing importance of flexibility in industrial competitiveness pointed out by analysts such Sabel (1986), surviving firms proved their adaptability to changing conditions. However, the costs of stockpiling materials imposed real losses in terms of efficiency taking these Latin American firms further from the Japanese model of

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[3] We also tested variables representing the share of inputs brought from other firms and an overall linkage variable (the sum of subcontracting to and for other firms), but these performed poorly. To test whether these linkages were related to firm size, we introduced into the regression models interaction terms representing these various forward, backward, or overall linkages with dummy variables for small, medium, and large firms. This effort was unsuccessful, and we found no evidence of an association between firm size and linkages. The failure of these results to support to our earlier statements on the differential response of small vs. large firms to recession are related to the high degree of correlation among variables.

just-in-time inventories and the tight network of firm subcontracting this model requires. Flexibility was the key to the survival of one of our largest and most efficient agricultural implements firms. Starting with over 80 employees, a majority skilled workers, this highly profitable firm sold exclusively through distributors. By 1986, the firm was still quite profitable with the same proportion of skilled workers. However, it was reduced to 18 employees, sold one-third of its output directly to consumers, shed some unprofitable product lines while reducing its materials inventory. It had also changed management. This is the subject of the next section.

The Problem of Managerial Know-How

Managerial know-how has been the focal point of efficiency measurement. It is the input that has been considered in short supply in developing countries and refers to both the technical and administrative aspects of managing production activities. The problem in these countries lies not so much on the lack of trained personnel to fill managerial positions, but rather on the incentives provided by the limited and protected markets. On the one hand, managers insulated from competition will likely not put forth the same effort as those motivated by it. On the other hand, even with some competition, in manufacturing sectors characterized by a few large firms and many small ones, the costs of and access to technical information will be even greater obstacles than in countries with less distorted industrial structures. It is no wonder that a key element in many developing country industrial policies has been the establishment of agencies to disseminate technical information. For example, Page's (1980) study of the efficiency of Ghanaian firms in timber-related industries concluded that training and extension programs for entrepreneurs could produce substantial efficiency gains, even in the context of protected markets that distorted factor proportions.

Entrepreneurial Organizational Capabilities

Previous attempts to explain TEIs (such as by Page (1984) described in Chapter 3) conclude that entrepreneurial and worker experience are the most important determinants of technical efficiency. Our results support this conclusion to a limited extent. As shown in Table 5.5, regression results for 1977 confirm the positive impact of entrepreneurial experience (which included all relevant experience in the industry or as a user of its products) and the more important role of university training.

By introducing our technical competence scores (for technical level or sophistication, design and engineering capabilities, and plant organization presented in Table 5.1) into the regression models, we tried to distinguish between the different, but very specific production-related, capabilities proxied by variables such as CEO experience or education. For 1977 we found that only plant organization contributed to explaining TEI variation, though the negative sign of this coefficient was unexpected. A potential explanation concerns the managerial hierarchy this variable may reflect; firms with the highest scores for plant organization tended to have more management personnel. The most efficient firms managed their operations with a small core of managers, often only the entrepreneur and a plant foreman in the case of smaller firms.

By 1986, however, the recession brought leaner management and the plant organization variable picked up the trends to rationalize production operations in an effort to cut costs. Similarly, the technical level variable picked up the importance of fairly complete, if not sophisticated, equipment. The aging of the two industries in the sample brought about a greater professionalization of production operations, and, as a result, entrepreneurial experience and education no longer contributed to explaining TEI variation.

In fact, in terms of their association with the TEIs, entrepreneurial experience like age of firm registered negative zero-order partial correlation coefficients for 1986. Nine years after the first survey, the average entrepreneur claimed almost 25 years of experience, and in terms of firm size, older entrepreneurs concentrated in smaller firms claiming almost 30 years of experience compared to 19 years for larger firm CEOs (see Table 5A.4 in Appendix C). Furthermore, the percentage of entrepreneurs receiving additional training (through participation in courses, workshops, seminars) dropped from almost half in 1977 to one-quarter in 1986. Most entrepreneurs did not keep up with new methods in the technical or administrative area. Indeed, many entrepreneurs of all ages noted how tiring it was just to keep their firms alive even after the worse of the recession. Three quarters expressed a need for technical assistance, but slightly over 40% sought and received it, in most cases, from the government training agency, SENA. It seems, then, the problem was not the cost or availability of technical/managerial information, but of the entrepreneur's time. Although in the long term such efforts would have been worthwhile, in the short term their opportunity cost was unreasonably high given the immediate problem of surviving the recession.

Labor-Force Characteristics

Worker experience, as measured by average years with the firm, was not correlated with technical efficiency, contrary to Page's (1984) results. This variable showed little variation across firms although in 1977 larger firms tended to have more experienced workers. This probably reflected the greater difficulties of larger firms to avoid labor laws protecting seniority. After the recession, this difference across size groups vanished. We already noted the effects of the recession on labor: the decline in long-term contracts and the reduction in labor's share in value added. Slack demand together with the burden of labor legislation led firms to take drastic measures. For example, some medium-size firms, the most susceptible to unionization or worker suits filed in the Ministry of Labor, temporarily closed down their plant and set up separate companies to handle hiring.

In terms of other labor input measures, we found that the percentage of skilled workers (whether as a percentage of production or total workers) showed a negative correlation with technical efficiency. This perverse relationship suggests that firms found to be efficient under our TEIs, achieved this efficiency with a relatively unskilled work force. Those firms with higher participation by skilled workers and technical professionals may simply not have learned to use their talents effectively. This is the case with firms relying on unit-by-unit production processes. In terms of technical professionals, a key argument in the flexible specialization literature is confirmed by entrepreneurs' complaints of engineers who refuse to "get their hands dirty" on the shop floor.

The capital equipment available to workers may be the more important determinant of technical efficiency. The key aspect of capital is vintage; later vintages embody the latest technology. Unfortunately, existing TEI studies do not have data regarding the vintage of capital. CBI in their analyses tested a variable representing the percentage of second-hand equipment, but found little relationship with technical efficiency. Our vintage variable also performed poorly in 1977 models but, contrary to our expectations, in the 1986 model, contributed positively to technical efficiency; a 10% increase in the vintage of capital was associated with an increase of about 4% in technical efficiency. We surmise that this seemingly contrary evidence is because workers had more experience working with older vintage machinery and this learning process was reflected in greater efficiency. These results tend to support Pack's (1984) findings in his study of productivity in the Philippine textile industry. He found that firms with newer equipment had lower relative efficiency because of suboptimal usage--management and workers lacked the technical know-how or experience to use this equipment efficiently.[4]

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[4] Pack (1984) suggests that this is a problem of inappropriate factor proportions; firms miscalculate the type and quality of inputs they will need, in the Philippine case the miscalculation involved spare parts. This together with the negative impact of capital intensity on TEIs (Table 5.5) provides a hint that for those firms which renovated their capital stock, at least during the sluggish demand faced in 1986, capital intensity aggravated the problem of lower capacity utilization.

Patterns of Profitability

A critical element in firm performance is profitability and one of its leading determinants should be technical efficiency. Indeed, under perfect competition the most efficient firms should be the most profitable (setting aside the broader issue that under these conditions profits should fall to zero in the long-run). Comparison of TEI patterns in Table 5.2 and those of the price cost margin (PCM)or profitability indicator, shown in Table 5.6 suggests this may be true. In general, technically efficient firms were also the most profitable. The least efficient followed the pattern noted by CBI (1989) in which very small firms (with fewer than 10 workers) managed by former blue-collar workers held on to a marginal existence. These entrepreneurs value their independence and so apparently underestimate the opportunity costs of their time. Table 5.6 also confirms the macro trends noted in Chapter 4 with respect to the profitability decline and the increasing capital costs between the two survey years.

TABLE 5.6

PROFITABILITY AND CAPITAL COSTS BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in percent

Year/	All	Industry		Number of Employees		
Item	Firms	Agricult.	Kitchens	1-20	21-40	41+
1977:						
PCM	59.3	60.4	57.6	51.4	62.0	69.0[b]
(s.d.)	(20.8)	(19.2)	(23.4)	(22.8)	(16.0)	(17.8)
$ATRR_{vt}$	5.3	4.7	6.2[c]	5.4	5.0	5.5
(s.d.)	(2.7)	(2.9)	(2.2)	(2.8)	(2.7)	(2.7)
1986:						
PCM	58.2	62.2	53.8	56.2	55.0	70.0
(s.d.)	(18.0)	(18.5)	(17.1)	(21.6)	(15.5)	(15.4)
$ATRR_{vt}$	7.6[a]	7.0	8.2	7.1	7.1	9.6
(s.d.)	(3.3)	(3.2)	(3.3)	(2.8)	(3.7)	(3.1)

Agricult.: agricultural implements; kitchens: kitchen equipment; PCM: price-cost margin=(Value added-total wage bill)/Value added; $ATRR_{vt}$: after-tax real cost of capital. Means for given group (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level.

When we examined the determinants of profitability, we found once again that firm size contributed little when other variables representing production characteristics were present. As shown by regression model results in Table 5.7, TEIs alone accounted for about half of PCM variation for both years. The TEI coefficient remained fairly stable across years and alternative measures; a 1% increase in technical efficiency was associated with an increase in profitability of .2%. On the other hand, other coefficients were not so stable. For example, longer-term labor contracts, despite their higher costs, added to 1986 profitability. Although labor stability proved unrelated to our TEIs, this surprising association with profitability may reflect the administrative costs imposed by worker turnover.

TABLE 5.7

REGRESSION RESULTS: DETERMINANTS OF PROFITABILITY

Standard Error in parentheses

Independent Variables	PCM as dependent variable regressed on Ln TEI based on LUE and			
	1977		1986	
	p_k	p_{vt}	p_k	p_{vt}
Constant	0.61[a]	0.54[a]	0.46[a]	0.37[a]
	(0.09)	(0.10)	(0.09)	(0.11)
Labor Contract	-0.15[b]		0.08[b]	
(longer term=1)	(0.05)		(0.04)	
Quality premium	0.07	0.11[b]		
(adjusted/actual)	(0.06)	(0.05)		
Ln TEI	0.25[a]	0.20[a]	0.28[a]	0.27[a]
(see column head)	(0.03)	(0.04)	(0.04)	(0.06)
Technical level	0.26[a]	0.32[a]	0.19[b]	0.26[b]
(% of top score)	(0.09)	(0.10)	(0.08)	(0.10)
Design/Engin. level			0.20[c]	0.33[b]
(% of top score)			(0.12)	(0.14)
R^2 adjusted	0.59	0.64	0.69	0.56
N (observations)	50	50	26	26
F	18.76[a]	22.83[a]	14.94[a]	11.48[a]

PCM: price-cost margin=(Value added- total wage bill)/Value added;Ln- natural logarithm; LUE- labor in unskilled equivalent person days; p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; Quality Premium, see Table 5.11; Regression coefficients are significant at the:a= .001 level; b= .01 level; c= .1 level. Other financial characteristics tested are in Table 5A.7 in Appendix C.

The importance of the firm's design and engineering capabilities reflect two trends: first, the professionalization of management noted earlier, and second, increased marketing efforts. During the high demand of 1977, 40% of firms made no specific marketing efforts relying exclusively on word of mouth. By 1986 less than a quarter continued to rely on their clients for advertising.[5]

The Evidence on Technical Progress

In order to examine the movement of the best-practice frontier, we followed the Nishimizu and Page (1982) methodology of pooling both year's data and minimizing the error or technical inefficiency term across years as well as firms. The reliability of the resulting estimates, shown in Table 5.8, hinges upon the accuracy of the implicit deflators used to adjust output and inputs (see Technical Appendix). The figures in the table lend no support to the claim of technological decline in the case of these two industries.

TABLE 5.8

POOLED TECHNICAL EFFICIENCY INDICES (TEI) BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in percentages with respect to the best-practice frontier

Year/ TEI Measured with	All Firms	Industry		Number of Employees		
		Agricult.	Kitchens	1-20	21-40	41+
1977:						
p_K-LUE	39	45	31[b]	42	33	41
(s.d.)	(22)	(19)	(24)	(24)	(18)	(21)
p_{vt}-LUE	37	41	31[c]	35	34	43
(s.d.)	(21)	(18)	(24)	(24)	(16)	(20)
1986 (constant pesos):						
p_K-LUE	45	55	36[c]	49	39	57
(s.d.)	(28)	(28)	(27)	(34)	(20)	(39)
p_{vt}-LUE	45	56	35[c]	46	41	59
(s.d.)	(31)	(30)	(28)	(38)	(22)	(37)

Agricult.: agricultural implements; kitchens: kitchen equipment; p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LUE: labor in unskilled equivalent person days; p_{vt}: disaggregated measure of capital flow. Means of respective groups (by year, industry, and size) are significantly different at the: a=.001 level; b= .01 level; c= .1 level.

Comparing the above table with the base case TEIs in Table 5.2 shows that although kitchen equipment firms significantly increased average efficiency in 1986, the

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5 We did not have data to quantify firms' marketing efforts. Part of the problem was the wide variation among those firms doing nothing, those doing some advertising (in newspapers and trade publications), and those hiring full-time salespeople.

frontier firms in this second year only slightly pushed out the best-practice frontier. Agricultural equipment producers demonstrated clearer gains despite the devastating effect of the recession on this industry (see Table 5A.8 in Appendix C). To examine this relationship more systematically we estimated regression models to "explain" changes in technical progress across firms. Table 5.9 presents our results in explaining the variation in the level of technical progress (pooled TEI) for 1977 and 1986 and the changes between these two years. In the context of technical progress, the model of the 1986-1977 changes is the most meaningful because it looks at the changes in the best-practice frontier. It shows that cumulative efficiency improvements as well as entrepreneurial efforts helped to push out the frontier. The importance of static efficiency in the initial year to dynamic TFP gains confirms similar findings by Caves and Barton (1990).

We tested a variety of proxies for entrepreneurial effort, including changes in product design, additional training, and recourse to different sources of information or technical assistance by the entrepreneur, most of which abated with the demands for survival in the recession. The two proxies that did contribute to the explanatory power of the regression model were changes in production method and in technical level. Changes in technical level, reflecting improvements in terms of the completeness and sophistication of machinery, performed better than variables specifically quantifying the replacement rate of capital assets (net change in capital stock as a percentage of total 1986 capital stock; see Table A.4 in the Technical Appendix) or the changes in factor proportions. Changes in production reflected improvements in processes, particularly their rationalization. Between the survey years, there was a shift from increasing mechanization reported by the majority in 1977 to reorganization of production.

We also included in the 1986 and 1986-77 models a dummy variable denoting change in the primary product to pick up the changes in production this may require and the potential biases from our implicit output deflators derived from incomplete price and quantity data. The efficiency losses caused by such dislocation are illustrated in table below.

TABLE 5.9

REGRESSION RESULTS: DETERMINANTS OF TECHNICAL PROGRESS

Standard Errors in parentheses

Independent Variables	Pooled Ln TEI as dependent variable based on LUE and					
	1977		1986		Changes 86-77*	
	p_k	p_{vt}	p_k	p_{vt}	p_k	p_{vt}
Constant	-0.52[a]	-0.48[a]	-0.37	-0.75[c]	-0.03[c]	-0.02
	(0.07)	(0.07)	(0.36)	(0.48)	(0.07)	(0.06)
TEI	0.88[a]	0.96[a]	1.15[a]	1.19[a]	0.16	0.45[a]
(ln for 1977,1986)	(0.06)	(0.04)	(0.22)	(0.29)	(0.11)	(0.12)
$ATRR_{vt}$		-0.02[c]				
(percentage)		(0.01)				
Design/Engineering			0.36	1.13		
(% of top score)			(0.55)	(0.75)		
Technical level					0.19[b]	0.24[a]
(% of top score)					(0.07)	(0.06)
Product design	0.13[c]	0.12[b]				
(change=1)	(0.07)	(0.06)				
Primary product			-0.14	-0.29	-0.15[b]	-0.17[b]
(change=1)			(0.17)	(0.23)	(0.07)	(0.06)
Production method					0.16[b]	0.10
(change=1)					(0.08)	(0.07)
R^2 adjusted	0.82	0.93	0.55	0.46	0.29	0.46
N (observations)	50	50	27	27	26	26
F	115.27[a]	202.87[a]	11.44[a]	8.32[a]	5.52[a]	10.70[a]

* Dependent variable not logged and independent variables refer to 1986-77 changes; Ln: natural logarithms; LUE: labor in unskilled equivalent person days; p_k: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow. Regression coefficients are significant at the: a= .001 level; b= .01 level; c= .1 level.

These results are confirmed by examining those firms that pushed out the best-practice frontier. In the case of agricultural-implement producers, two very different firms were responsible for this technical progress. The first employed 90 employees compared to 12 for the second and produced over 10 times the latter's sales volume. Neither of these firms produced on the frontier in 1977, but the changes they instituted since then were key. The large firm began to take the competition from smaller firms more seriously after witnessing the decline of one of Colombia's oldest and largest machinery producers. Instead of continuing the practice of price leadership (exerted by the larger older firm just cited), the managers of this large firm reduced management layers, realigned its product prices with those of smaller competitors, and initiated an aggressive advertising, sales and service campaign through its distributors. These changes were implemented by a new CEO, who unlike his predecessor, managed to restore peace with the firm's labor union.

The small 12 worker firm, basically a family operation, stands out as unique for its purchase of programmable second-hand equipment. The purchase and successful incorporation of this equipment were no doubt due to the tireless efforts of the entrepreneur (as leader of a cooperative of small and medium scale firms to improve their access to capital and material inputs), his wife (as accountant and sole marketing expert), and their son (as plant foreman responsible for adapting the new machines to the firm's operations). In addition, we must note that in this decision to increase automation, substitution of skilled labor was a consideration. This firm reported its reluctance to increase employment for fear of the costs of labor legislation and scarcity of responsible competent workers. This is a clear example where programmable equipment vitiated the traditional trade-off between flexibility and the low-cost high-productivity associated with automated high volume production. This type of equipment is rare in Colombia and most entrepreneurs still considered this an alternative for only the largest producers.

The frontier firms among kitchen equipment producers were also represented by a small (10 employees) and a large firm (57 employees), but they used different strategies from those detailed above. The small firm defined the best-practice frontier in 1977, grew to 31 employees by 1986, but despite its attention to pre-production planning remained on the frontier only under the full-capacity and price-quality comparability alternatives. What was a very complete capital stock in the first survey year remained essentially unchanged by the second. The large firm also increased its employment over the survey years, but managed to push out the frontier. It renovated some of its equipment to accommodate a larger workforce, but exercised strict control over its workers by paying them in accordance with their output. All frontier firms in both industries focused on containing unit costs to be able to offer lower product prices. For kitchen equipment firms, this seemed the sole objective; they made no conscious efforts to improve upon the techniques currently used in their production, claiming they were well tested and routine.

The strategy toward decreasing labor demands and associated costs was a common feature not only of frontier firms but also of surviving firms as we noted earlier. Although real wages made slight gains, as shown in Table A.3 in the Technical Appendix, workers' relative power declined during the survey period. Only in the case of production workers in the large agricultural frontier firm did union negotiation assure substantial increases in fringe benefits and smaller job losses relative to management. However, even in this case Colombian workers lost out by this firm's decision to set up a plant in Ecuador rather than continue to export. In terms of the future competitiveness of Colombian industry, this strategy and the general climate of labor-management confrontation, will present further obstacles to achieving the productivity standards of the model of flexible specialization with its reliance on shop floor cooperation.

Finally, with respect to the hypotheses about firm size and managerial know-how, once again we found that size was not systematically related to technical progress nor was such progress correlated with specific managerial capabilities. Similarly, factor proportions were not systematically related to technical efficiency. More important were the characteristics of the organization of production and the firm's ability to adjust them to changing circumstances. TEI rankings for 1986 were not significantly different from those for 1977. Although the firms defining the frontier changed in the case of the more competitive agricultural equipment market, efficient and inefficient firms tended to remain at the top and bottom, respectively, of the distribution of TEI rankings across the survey years.

Evaluation of Measurement Methodologies

In Chapters 2 and 3 we discussed the potential biases introduced by capacity underutilization and non-competitive markets . Although we have touched on these issues, in this section we briefly evaluate the adjustments applied in this study. This evaluation entails a comparison of TEI patterns for the base case with those generated by correcting for each of these disequilibria. We also evaluate the gains from disaggregation by comparing the alternative measures of capital and labor, unweighted versus weighted.

Prices Under Disequilibrium

We expected our admittedly second-best adjustments to show that TEIs would improve as firms moved to operate at full capacity, on one hand, and charge prices commensurate with their quality, on the other. In both cases average technical efficiency declined. In the case of quality correction, comparing base case and quality-adjusted TEIs for 1977 shows that while average efficiency declined, this decline was greatest for kitchen equipment and medium-scale firms (see Table 5.2 above and Table 5A.9 in Appendix C). These trends are understandable for the latter size group because they already enjoyed price-quality comparability in 1977 (see Table 5A. 11 in Appendix C). By the same token, we expected that because of their high quality premia, the average efficiency levels of kitchen equipment would rise rather than fall after adjustment. In fact, with respect to best practice average output levels fell by 8%-16% with the higher figure corresponding to TEIs based on the aggregate capital measure. A possible explanation is that those with the higher quality premia were not the most efficient (according to our base case TEIs) producers, i.e., those defining the production frontier. Instead, the latter were penalized (or more accurately, not favored by the quality premium because they were close to price-quality comparability) and consequently brought down average efficiency levels for that industry.

In the case of the capacity utilization adjustment we find once again that the gains in efficiency of those most affected by disequilibrium did not compensate for the losses of those less affected, but more efficient (see Tables 5.2 above and 5A.10 in Appendix C). Samplewide, capacity utilization fell from 78% to 60% between the survey years (see Table 5A.12 in Appendix C). Kitchen firms experienced the steepest decline, but agricultural equipment producers registered the lowest absolute levels. The TEIs based on the disaggregated capital measure show that these firms would have averaged about 7% greater output under full capacity.

By 1986 price-quality distortions and their dispersion across firms was down to a minimum; compared to less than 20% in 1977, about half of the surviving firms in both industries felt their prices were in line with their product quality. This reduction in firm market power exercised through product prices is confirmed by Table 5.11 which compares the rankings of base case and price-quality corrected TEIs. In contrast, capacity underutilization became a problem in 1986; the Spearman rank coefficients for 1986 full capacity and base case TEIs registered the lowest correlation among the comparisons presented.

TABLE 5.11

COMPARISON OF BASE CASE AND ALTERNATIVE TEIS

Spearman rank correlation coefficients (in percent)

Year/ Item	Base case vs. Price-quality corrected TEIs		Base case vs. Full Capacity TEIs	
	p_K-LUE	p_{vt}-LUE	p_K-LUE	p_{vt}-LUE
TEIs:				
1977	84[a]	72[a]	88[a]	84[a]
1986	95[a]	78[a]	54[a]	35
Pooled TEIs:				
1977	94[a]	90[a]	92[a]	88[a]
1986	96[a]	94[a]	68[a]	68[a]

p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LUE: labor in unskilled equivalent person days. Spearman's r is significant at the: a= .001 level.

Gains from Disaggregation of Labor and Capital

Earlier in this chapter we explained the rationale behind disaggregation and noted that although widely accepted for labor there are no comparable applications, except the present, for capital. In spite of the very different formulas for the aggregate (p_K) and disaggregated (p_{vt}) measures of the rental price of capital, we reported zero-order partial correlation coefficients of 88% and 77% for 1977 and 1986, respectively. This high correlation demonstrates the beneficial impact of using more accurate data (rather than universal assumptions) regarding mean service life and vintage in the aggregate capital flow formula, thereby producing an improved aggregate measure. We suspect that even when detailed information by individual asset is unavailable, estimated averages of these two parameters for machinery and buildings would represent an improvement upon universal assumptions.

We consider more important a comparison of the results of manipulating alternative measures than comparisons of the values of these measures. Table 5.12 illustrates the corresponding Spearman rank and zero-order partial correlation coefficients for two important variables used in this study: TEIs and capital-labor ratios.

The correlations are fairly high once again. For the base year 1977, it appears that if we decide to apply the disaggregated labor measure (LUE), even in the case of metal-mechanical industries where capital needs are demanding and indivisibilities apply, an improved aggregate capital measure would not yield substantially different results. This is confirmed by the results of our regression models; in the TEI, capital intensity, PCM and pooled TEI models, the coefficients are quite similar. Only if we consider the goodness-of-fit indicators (the R^2 adjusted and the F statistic) can we conclude that our disaggregated capital measure (p_{vt}) performs somewhat better.

TABLE 5.12

COMPARISON OF ALTERNATIVE CAPITAL AND LABOR MEASURES

Correlation coefficients (in percent)

Year/Item	Comparison of p_K vs. p_{vt} measured with LUE	Comparison of p_K vs. p_{vt} measured with LPD	Comparison of LUE vs. LPD measured with p_K	Comparison of LUE vs. LPD measured with p_{vt}
Spearman rank for **TEIs**:				
1977	92[a]	84[a]	83[a]	89[a]
1986 (current)	77[a]	81[a]	80[a]	87[a]
86-77 change	71[a]	72[a]	65[a]	84[a]
Zero-order partials for **capital-labor ratios**:				
1977	88[a]	87[a]	98[a]	98[a]
1986 (current)	71[a]	98[a]	59[a]	53[b]
1986 (1977$P)	77[a]	98[a]	59[a]	91[a]
86-77 % change	66[a]	64[a]	56[a]	97[a]

p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LUE: labor in unskilled equivalent person days; LPD: labor in person days; 1977$P: 1977 constant pesos. Correlation coefficients are significant at the: a= .001 level; b= .01 level.

As we move away from the base year, however, the problems of aging and incorporating real additions/deletions to the capital stock became issues of concern in the choice of alternative capital measures. The table above shows a fairly steep drop for 1986 in rank correlation of current peso TEIs based on aggregate versus disaggregated capital measures. The same holds true for current peso capital-labor ratio measures. On the other hand, the two capital measures are more highly correlated in their constant peso formulation, but the 1986 models based on p_{vt} slightly outperform those based on p_K. In the case of p_K, we used the published deflators to deflate 1986 replacement costs. For p_{vt} we had enough information from entrepreneurs to age the capital stock incorporating additions and deletions in terms of their 1977 replacement costs. The additional information on 1986 replacement costs allowed us to derive the implicit deflators, which we then compared against those published by the Central Bank (see Table A.3 in the Technical Appendix).

As the above table shows, the differences between capital measures are magnified when we compare 1986-77 changes in TEIs and capital-labor ratios. By examining the individual cases or firms for which alternative measures of capital-labor ratios differ most, we can piece together the source of these differences. Alternative estimates of changes in capital intensity differ the most in those cases where changes in capital equipment have involved sophisticated or used machinery. The p_K measure will underestimate the change in the case of sophisticated machinery for which appreciation has been greater compared to more simple equipment. It will overestimate the change involving used machinery for which depreciation has been greater compared to new equipment. Even this improved aggregate measure averages out the capital changes based on universal deflators and averages for mean service life and vintage.

Table 5.12 also illustrates that the biggest differences between alternative measures show up between wage-weighted (LUE) and unweighted (LPD) labor measures when combined with aggregate capital (p_K). When combined with p_{Vt}, resulting estimates are quite comparable. It is as though changes in capital overshadowed changes in labor which were almost uniformly towards a reduction of workers and/or hours worked and of the differential between unskilled and other production workers wages, thereby reducing the differentials between the two labor measures.

CONCLUSIONS

Our research used the tools of efficiency measurement to examine patterns of efficiency in two Colombian metal-mechanical industries. We used firm TEIs to test hypotheses regarding the characteristics of firms in developing countries with long histories of import substitution. First, we found no systematic relationship between technical efficiency nor technical progress and firm size. This suggests that the issue is not that small or large is efficient, except in the case of the very small which fall below minimum efficient scale for these industries. There are a range of plant scales consistent with technical efficiency. In other words, within a given technology (what is referred to as the ex-ante choice) there is flexibility allowing a range of factor proportions (ex-post) and types of plant organization.

Although the patterns of capital-labor ratios support the existence of capital indivisibilities, we could not conclude that differences in factor proportions were potential causes of technical inefficiency. In the second survey year, capital intensity was associated with lower TEIs, but this reflected the severe problems of capacity underutilization affecting both industries.

Second, the most important determinants of technical efficiency change with market circumstances. In the first survey year we found that the entrepreneur's experience and education were key variables. By 1986 with the maturing of both industries and the trial by fire represented by the recession, the general level of managerial know-how had increased and more specific production-related capabilities and efforts became important. Most important, however, were the difficulties in obtaining material inputs whose stockpiling imposed real efficiency losses and took Colombian firms further away from the ideal of the flexible specialization model and its reliance on just-in-time inventories.

Another obstacle to the achievement of this ideal was presented by a survival strategy based on labor discipline as firms pursued short-term goals of cutting costs. The recession provided an opportunity to reduce employment as well as labor's share. Without doubt, the impact of this antagonistic labor-management relationship will have repercussions for future productivity gains.

Third, our examination of productivity changes provided no evidence of technical regress in these industries. The firms who pushed out the best-practice frontier were represented by small as well as large firms and their strategies reflected different industry conditions. The death of one-third of the agricultural implements firms in the sample led to a modest renovation of its capital stock. The retreat from trade liberalization did not put an end to competition, but rather an end to the cut-throat price wars of the 1970s between small and large long-established firms. For kitchen equipment firms recession signalled the closing of only one firm, but the reduced demand of the 1980s brought on a competitive race for customers that focused firm strategies on cutting costs.

Nevertheless, we also found that TFP gains across survey years was strongly associated with firm relative technical efficiency in the initial survey year. This suggests that static efficiency in one period strongly affects dynamic productivity gains in the future. We would expect, therefore, that agricultural implements producers will in the future once again show greater TFP gains relative to kitchen producers. The latter have focused on cost-cutting and see any further improvements in technique as unwarranted by current market conditions.

Fourth, in terms of measurement methodology, we found that the comparison of base case and adjusted TEIs yielded unexpected results. Although we had evidence that capacity underutilization and non-competitive product pricing were market factors in 1986 and 1977, respectively, we found they did not significantly bias technical efficiency and TFP estimates. For inefficient firms affected by these market factors, we found these were not the only causes of their relative inefficiency; in the absence of this disequilibria, they were still disadvantaged by more fundamental problems. For example, in the case of the full capacity adjustment, our examination of their answers suggests that those entrepreneurs most affected by underutilization may not have correctly evaluated the costs of higher utilization of their capital equipment. In part, this reflected their interpretation of the full capacity question as an inquiry into the technical limits of their equipment thereby skewing estimated input mixes.

In terms of the measurement of capital and labor, we found that the gains from disaggregation were confirmed by a slightly better fit of regression models. Our evaluation of the traditional aggregated and the data-intensive disaggregated measure of capital yielded no significant differences although our aggregated measure benefitted from specific information regarding vintage and service life. If we compare even our improved measure aggregated capital measure with CBI's version, we do note significant differences leading to very different patterns in capital-labor ratios. However, the demands of disaggregation are directly related to the heterogeneity of inputs and outputs.

We leave the policy implications and new research questions to be addressed for the next and final chapter.

CHAPTER 6

SUMMARY AND CONCLUSIONS

We have organized this chapter into four sections. The first sets out the purpose and hypotheses of the research described in the preceding chapters. The discussion then turns to a brief review of the approach and methodology we chose to guide our hypotheses testing, including an explanation of how we dealt with the practical difficulties of operationalizing the methods described in Chapters 2 and 3. In the third section we report the results of our analyses and compare them to similar studies, including the Cortes, Berry and Ishaq (CBI, 1987) work which provided the base year data for our 1977-1986 comparison of firm performance. We conclude by examining the policy implications of our results and suggesting new directions for future research.

PURPOSE OF RESEARCH AND HYPOTHESES TESTED

The focus of this research was to examine and quantify as accurately as possible the changes in productivity in two metal-mechanical industries. Through these changes in productivity we traced the changes in the relative efficiency of firms and by comparing the movements of those firms defining best-practice production techniques we traced technical progress. The purpose of this study of efficiency and technical change was, first, to be able to evaluate firm economic performance, and second, to uncover what firm strategies made for success or failure in difficult market circumstances. The ways firms managed the limitations and opportunities presented by the production environment would identify those policies most, or, alternatively, least supportive of efficiency in production.

The literature on productivity measurement in LDCs has focused on the interrelated issues of firm size, efficiency, and factor proportions. In many cases the industrial structure established under import substitution has led to a skewed size distribution of firms characterized by few large and many small firms. Such a skewed distribution cannot be justified by small domestic markets alone. The controversy lies in how these firms are evaluated; namely the arguments focus on why large or small firms are more efficient. On one hand, large firms exploit economies of scale whereas the small fall below the minimum efficient scale. In spite of their scale inefficiency, these small firms survive, however, because of limited import competition. On the other hand, many argue that because they save on scarce capital and make use of abundant LDC labor supplies small firms are allocatively efficient. Their factor proportions reflect the relative scarcities in developing economies. Large firms, in contrast, respond to the distorted incentives of protectionist policies and can be neither allocatively nor scale efficient--they are too capital intensive and their scale of operations too large for the domestic LDC market.

Moreover, without the incentives of competition, LDC managers fail to produce the maximum with given inputs. Even if they purchase inputs in the correct proportions, they fail to use them optimally because they lack the training or motivation to keep up with technical and administrative methods. Usually, this problem of technical inefficiency is traced to the lack of training for small firm managers and to a lack of motivation for those in large firms. Recently, attention has focused on another aspect of managerial capabilities. Given the instability of markets, some claim small firm managers are more flexible or adaptable because they are unencumbered by internal bureaucracies and rigid labor contracts. Nevertheless, large firm managers can draw upon greater resources with which to weather changing market conditions. These characterizations of small versus large firms are an empirical matter and form the first group of hypotheses we tested.

The second set of hypotheses focused on technical progress. The difficulties faced by most Colombian firms in the 1980s led some analysts to claim technical stagnation in the face of recession, trade restrictions, and financial crises. Firm survival strategies had to focus on cost-cutting, setting aside for more propitious times specific efforts towards technical improvements. If we extrapolate efficiency at a given time to future gains in productivity, these dynamic losses would set Colombia further behind international best practice. An alternative interpretation focuses on the salutary effects of the increased competition accompanying reductions in aggregate demand. In order to survive, firms are forced towards greater efficiency and thereby necessity becomes the catalyst for technical progress.

We chose to focus our empirical efforts on the metal-mechanical sector because it most closely corresponds to the usual definition of the capital goods sector. Although the industries we studied, agricultural and kitchen equipment, represent the beginnings of a capital goods sector in Colombia, their experience offers an indication of how the country might fare with more sophisticated industries in this sector during later phases of its technological development.

APPROACH AND METHODOLOGY

In order to quantify relative efficiency levels across firms and productivity improvements in time, we chose the firm as our unit of analysis. Increasingly, even in studies of industrial structure, firm-level data are being used to avoid confusing the various and interrelated characteristics of production--bias, elasticity, scale, efficiency, and homotheticity. These are the basic concepts of neoclassical production theory which guide most production function estimation and analyses. On one hand, these analyses tell us whether our assumptions about the underlying production technology are correct. They quantify the technical characteristics of production with respect to the average production function. In the case of efficiency, this average is not particularly useful as a benchmark for evaluating firm performance. For this purpose we need a tool that will get us closer to the true meaning of the production function which defines the different input combinations that can produce maximum output. The tools of efficiency measurement, specifically the frontier production function, provide the appropriate benchmark by allowing us to quantify firm efficiency with respect to the best-practice frontier.

In Chapter 2 we reviewed neoclassical models that attempt to decompose productivity change into improvements in the use of factors, and the unexplained TFP residual we interpret as technical change. In addition to TFP refinements concerning disaggregation, the measurement of capital, and adjustments for disequilibrium conditions, we explained in Chapter 3 how frontier methods further decompose the TFP residual by accounting for errors in optimization. Indeed if markets were perfect and technology and information freely accessible, we would not need to worry about such errors. Prices would provide correct signals to direct the use of factors and informed or unmotivated managers would be replaced. However, our analysis in Chapter 4 of the context in which Colombian metal-mechanical firms operate suggested errors in optimization are likely to be very important. Even our limited review of frontier studies in Chapter 3 demonstrated that errors in optimization are important in Colombia, India as well as the United States.

With limited data, the diagnosis of these errors is not simple since there are three types of errors in optimization manifest at the firm level and their origins lie in the interrelated technical characteristics of production. Our empirical work focused on technical inefficiency and used technical efficiency indices (TEIs) to examine the other two types of errors--scale and allocative inefficiencies. Once calculated, our firm efficiency rankings allowed us to investigate the relationship between technical efficiency, size and factor proportions. Most frontier studies focus on the relationship between size and TEIs which involves testing hypotheses concerning issues of scale--the existence of capital indivisibilities and/or economies of scale. A few frontier studies also examine the relationship between factor proportions and TEIs to study allocative inefficiency. Our frontier study has taken efficiency analysis one step further by attempting to account for disequilibrium conditions. Specifically, we analyzed the impact on TEIs of distortions in product pricing and the other source of price or allocative inefficiency, capacity underutilization.

With frontier methods we quantified errors in optimization and examined the relative efficiency of small versus large firms. In order to estimate firm-specific efficiency rankings we applied deterministic frontier methods using linear programming. By pooling data from both survey years we estimated the shifts in the best- practice frontier over these years to derive estimates of technical progress. The main disadvantage of the deterministic frontier is that it attributes all deviation from the frontier to technical inefficiency. By not allowing for random error, these frontiers yield upper-bound estimates of inefficiency, a fact which must be kept in mind when interpreting resulting TEIs. Another important disadvantage is the sensitivity of the deterministic frontier to extreme or outlier data. We have tried to mitigate this by re-estimating the frontier without the most efficient observations until frontier parameters stabilize.

Although our sample was small, beginning with 50 firms in 1977 and following up with 27 firms in 1986, we calculated two separate Cobb-Douglas production frontiers for the two industries included, agricultural and kitchen equipment. Despite their common classification within metalworking, these industries have different production technologies. These differences are reflected in the completeness, type and sophistication of their machinery. This limited number of observations precluded estimation of stochastic frontiers as well as more flexible forms. Stochastic models offer the most theoretically appealing approach because they explicitly incorporate random error and offer the possibility of mitigating important deficiencies in data. Moreover, since we had only two time periods we could not take advantage of panel data analysis to derive firm-specific TEI that would allow variation in technical efficiency across time as well as units (as done by Cornwell, Sickles and Schmidt, 1989). Based upon the comparison of functional forms and frontiers by Corbo and de Melo (1986) for Chile for nonelectrical machinery, there was no a priori evidence that the Cobb-Douglas specification would be inappropriate. We therefore decided to focus on what the literature points to as the most serious problem in frontier estimation--the measurement of inputs and outputs, particularly capital. These issues are discussed in the following section.

Practical Difficulties with Measurement

Although our Colombian data are rich with qualitative and quantitative data on firm performance for the years 1977 and 1986, the sample is small as we noted above. Most important, this sample lacks complete price and quantity data on all inputs and outputs. Our labor, and particularly, capital input data are unusually detailed, but incomplete quantity information on output precludes estimation of dual cost or profit functions that would allow us to systematically analyze allocative efficiency. Nevertheless and despite incomplete price and quantity data, we examined the potential biases of allocative inefficiency by studying the relationship between TEIs and factor proportions. To pinpoint further the possible sources of this type of inefficiency we compared these relationships using market prices with those obtainable in the absence of market power and capacity underutilization, that is, after adjusting for disequilibrium conditions.

Thus, we chose to base our study of firms' relative performance on observed market prices and then compare these results to alternatives assuming equilibrium conditions to see the magnitude of the bias presented by the divergence between market and shadow prices. In effect, then, the ability of firms to claim higher product prices while minimizing factor input costs (through positive organizational measures, knowledge of import controls and practice in filing loan applications, or through the exercise of privileged connections) were reflected in higher TEIs for our base case scenario. Accordingly, we used the real market rates for capital offered by differing financing sources--own, commercial bank, public bank, or supplier/moneylender as well as market prices for labor and output. Our main adjustment involved a thorough consistency check to assure these data presented a reasonable picture of firm production and finances for the survey years. Even at the sectoral level where structural change and resource allocation effects are important, derivation and use of shadow prices in productivity analysis is only recently being developed. Although an imperfect tool, we derived alternative TEIs based upon full capacity and price-quality comparability to simulate the likely effects of disequilibrium conditions.

In addition to the issue of prices under disequilibrium, we had to deal with two other important and troublesome measurement problems. The first focused on aggregation within units of varied inputs and output and the second involved deflation.

As we noted in Chapter 2, index number formulas can guide us through proper aggregation by weighting different categories of an input according to the category's relative marginal productivity as reflected by its price. In terms of labor, we used relative wages to aggregate various labor types within the firm into unskilled equivalent person days. In the case of output, data on aggregate sales did not provide the necessary information for a similar weighting. This means, in effect, we assumed homogeneous output. In the case of capital, our sample provided rich detail about the vintage, service life, and cost of individual capital assets. This allowed us to apply Mohr's (1988; see Chapter 2 and the Technical Appendix) vintage rental cost of capital formula, which extends Jorgenson's original formulation based upon firm optimizing behavior and developed to solve the problem of the lack of directly observable capital input prices when assets are owner-utilized. Rather than resort to universal assumptions about useful life and vintage, our capital input estimates incorporate actual firm data.

Mohr's formula assures that all capital costs are decayed through a weighting scheme in which the importance of each vintage's cost decreases with age. This avoids the nagging problem of charging historical capital unreasonable current rates. To date, we know of no other application of Mohr's theoretically appealing formulation. This application, therefore, represents the most significant methodological contribution of our research.

Lastly, in order to avoid the problems of adjusting historical asset prices to a common base year, we used replacement costs. CBI based their capital input estimates on total capital stock valued at commercial cost, which would reflect the stock's historical cost in current pesos. However, as we explained in the Technical Appendix, by 1986, entrepreneurs were less certain of the prices their individual assets would sell for than the costs of replacing them. Regardless of the base used, deflation of asset prices to a common base year was needed to capture the real changes between 1977 and 1986. Since we had detailed information and many firms had made few changes in their capital stock, we were able to estimate implicit deflators to adjust our disaggregated capital measure. For the sake of a more complete and consistent valuation of individual assets we used replacement costs for capital. In the case of labor, we applied regional deflators published by the Central Bank hoping these would capture the improvements in the labor force brought about by greater access to education. In the case of output, we complemented 1977 and 1986 price data with the entrepreneur's and our own evaluation of how the product changed to derive implicit deflators. We fully acknowledge the difficulties of accurately capturing quality differences as well as changes in output mix in our 1977-1986 comparisons. Therefore, we introduced into our TEI regression models variables to capture the potential biases from these factors.

RESULTS FROM HYPOTHESIS TESTING

Using the tools of efficiency measurement we examined patterns of efficiency in two Colombian metal-mechanical industries. We used firm TEIs to test hypotheses regarding the relative efficiency of firms in developing countries with long histories of import substitution. First, echoing CBI's (1987) and Page's (1984) results, we found substantial scope for efficiency improvement, even considering that ,on average, technical efficiency reached a lower bound estimate of about 56% of best-practice output for both survey years. This difference between the average achieved and best-practice output cannot be attributed entirely to the random error component ignored in deterministic programming frontier models.

Second, we found no systematic relationship between technical efficiency nor technical progress and firm size. Only in the case of very small firms did we find evidence of capital indivisibilities. Especially in the case of agricultural implements producers, these firms were too small to support the number and variety of metalworking machines required by the production technology. In light of the indivisibilities and threshold effects of capital, we examined whether differences in factor proportions were potential causes of technical inefficiency. In the second survey year, capital intensity was associated with lower TEIs, but this reflected the severe problems of capacity underutilization affecting both industries. Overall, neither size nor factor proportions were systematically associated with technical efficiency.

This suggests that the issue is not that small or large is efficient, except in the case of the very small which fall below minimum efficient scale for these industries. Instead, we found a range of plant scales consistent with technical efficiency. Our firm sample did not support the popular myth of small labor-intensive firms. Measuring size by number of employees, we found that smaller firms were more capital intensive than larger ones who spread out their capital among a wider employment base. In addition, with the drawn out recession leading up to the second survey year, firms' growth patterns were disrupted. Instead of firms growing into their capital stock by adding workers, the recession forced medium-scale firms to reduce their employment thereby making the small firm group (with fewer than 20 workers) the most capital intensive. Similarly, we found little support for the myth of the large firm as capital intensive and burdened by excess capacity. Just as small firm entrepreneurs were able to maximize the use of their capital by subcontracting work to their employees, large firm entrepreneurs accomplished the same by diversifying their product line. In other words, in terms of technical, scale or allocative efficiency, size was not the most important factor. Within a given technology (what is referred to as the ex-ante choice) there was flexibility allowing a range of factor proportions (ex-post) and types of plant organization.

Third, the most important determinants of technical efficiency changed with market circumstances. In the first survey year we found that the entrepreneur's experience and education were key variables. By 1986 with the maturing of both industries and the trial by fire represented by the recession, the general level of managerial know-how had increased, and more specific production-related capabilities and efforts became important. Most important, however, were the difficulties in obtaining material inputs in the second survey year. Import restrictions resulted in firm stockpiling. This practice imposed real efficiency losses on all firms regardless of size or factor proportions and took Colombian firms further away from the ideal of the flexible specialization model and its reliance on just-in-time inventories.

Another obstacle to achieving this ideal was the firms' survival strategy based on cutting labor costs. The recession provided firms an opportunity to reduce employment as well as labor's share. We might interpret the puzzling negative relationship between TEIs and employee skill level as a sign of the impact of deteriorating labor-management relations or, at the very least, a sign of the inefficient deployment of labor; both cases are represented in the sample. In either case, this failure to maximize labor efficiency will have repercussions for future productivity gains.

These trends are particularly worrisome because we also found that TFP gains across survey years were strongly associated with firms' relative technical efficiency in the initial survey year. This suggests that static efficiency in one period strongly affects dynamic productivity gains in the future. We would expect, therefore, that agricultural implements producers in the future, once again, will show greater TFP gains relative to kitchen equipment producers. The latter tended to focus on cost-cutting and considered any further improvements in technique as unwarranted by current market conditions.

Fourth, our examination of productivity changes provided no evidence of technical regress in these industries. Small as well as large firms pushed out the best-practice frontier despite efficiency losses from stockpiling material inputs and cutting labor costs. Their strategies reflected specific industry conditions. The death of one-third of the agricultural implements firms in the sample led to a modest renovation of survivors' capital stock. The retreat from trade liberalization did not put an end to competition, but rather an end to the cut-throat price wars of the 1970s between small and large long-established firms. In the case of kitchen equipment firms, recession signalled the closing of only one firm, but the reduced demand of the 1980s brought on a competitive race for customers that focused firm strategies on cutting costs and improving production organization.

In terms of measurement methodology, we found that the comparison of base case and adjusted TEIs yielded unexpected results. Although we had evidence that non-competitive product pricing and capacity underutilization were market factors in 1977 and 1986, respectively, we found they did not significantly bias our indices of technical efficiency and technical progress. For inefficient firms affected by these disequilibrium conditions, we found these were not the only causes of their relative inefficiency; in the absence of disequilibria, they were still disadvantaged by more fundamental problems noted above.

In terms of the measurement of capital and labor, we found that the gains from disaggregation were confirmed by a slightly better fit of regression models. Our evaluation of the traditional aggregated and the data-intensive disaggregated measure of capital yielded no significant differences because our aggregated measure benefitted from specific information regarding vintage and service life. If we compare our improved aggregate capital measure with CBI's version, we do note significant differences leading to very different patterns in capital-labor ratios. However, the demands of disaggregation are directly related to the heterogeneity of inputs and outputs. In cross-sectional studies of firms with broadly similar production processes, the disaggregated capital measure is not likely to make a difference. This is not so in comparisons of varied firms across different time periods, particularly in the context of rapidly changing technology.

POLICY IMPLICATIONS AND NEW RESEARCH DIRECTIONS

Our findings support earlier results by CBI (1987) and Page (1984) regarding the inaccuracy of relating firm size and efficiency. In the metal-mechanical sector with its demanding capital requirements, neither size nor factor proportions are the main determinants of firm efficiency. This suggests that credit or trade incentives based upon firm size are not warranted since firm size is not a proxy for firm efficiency. As Little, Mazumdar, and Page (1987) conclude, only if small firms are more efficient in terms of their total factor productivity do they deserve special consideration. The insolvency or, at best, lack of sustainability of LDC development banks, whether for agricultural or industrial credit, confirms that preferential treatment for smaller producers is not an appropriate policy to promote efficient domestic production. Preferential access for larger producers is even less desirable because of its likely regressive distributional impact.

More important, as the recent work of Hernando de Soto suggests, is removing the obstacles to market entry faced by small producers. Our findings suggest to LDC policy makers that firm size, factor proportions, or even the presence of import competition per se are not all important. Both metal-mechanical industries we studied were established under import substitution. They have grown, however, in a climate of domestic competition as firms of different sizes have stolen the market share of long-established larger firms. As these industries mature and growth in the domestic demand for their products levels off, international competition and markets will become increasingly important. Accordingly, Colombian policy makers will have to overcome the main obstacles to efficient production we found in our 1986 analysis--access to imported material inputs and use of labor. It would seem that the standard popular prescriptions of trade liberalization (elimination of preferential treatment, exemptions and non-tariff mechanisms as well as reduction of the tariff levels and their dispersion) are warranted. However, these efforts must be complemented by measures to encourage greater competition, enforce and update labor legislation, and improve training and access to information for both management and labor.

In terms of specific efforts to speed technical progress, our findings echo those of Nishimizu and Page (1982) in which the scope for productivity improvements from technical efficiency gains appear larger and more immediate than those potentially available from expensive programs to promote research and development. In view of the aging capital stock of our surviving companies, replacement will become increasingly critical to efficient production. Our most efficient and technically progressive firms were those that either because of their greater resources or access to imports were able to replace their capital stock. In the case of our small 12-person firm, second-hand numerically controlled machines were obtained because of the entrepreneur's leading role in an association of small and medium-scale manufacturers. In the case of our larger firms, their knowledge of the import bureaucracy (INCOMEX) and ready access to capital allowed them to replace machinery selectively.

Finally, in terms of future research directions, we would recommend more concerted efforts to develop more complete and detailed firm-level data bases to allow systematic analysis of technical, scale and allocative inefficiency. Although recent research increasingly uses plant-level census data to study industry structure and performance, this does not preclude the need to develop a more detailed time-series for a subsample of units. If we are interested in looking into the "black box" of production, we need to put some effort into developing larger and richer data bases that will allow analysts to test theoretically rigorous, but data-intensive, stochastic frontier models.

A larger data base would have provided a firmer test of our hypotheses and allowed greater exploration of issues at which our limited data set only hinted. For example, with a greater number of observations, we could have tested the differential response of small and large firms to recession; as small firms seemed to turn increasingly outward to exploit their capital equipment, larger firms seemed to retract their linkages and opt for more vertical integration to accomplish the same purpose. As we noted in the introductory chapter, the metal-mechanical sector has historically played a key role in technology creation and diffusion because of its varied backward and forward linkages. Moreover, as the literature on flexible specialization suggests, but we could not test, the efficiency of firms may be tied to the efficiency of these linkages that traditionally in LDCs have not been well-articulated. It seems that future research efforts should focus on the nature of these linkages and their relationship to technical efficiency, firm size, and factor proportions. Such a study, particularly in a cross-country comparative framework, would help to explain the apparent dynamism exhibited by small firms and more fully capture their contribution to efficiency and technological mastery.

APPENDIX A

SOLOW'S MODELS OF TECHNICAL CHANGE

This appendix sets forth a more detailed explanation of Solow's most important models of technical change: disembodied technical change or total factor productivity (TFP) and capital embodied technical change.

THE AGGREGATE PRODUCTION FUNCTION AND DISEMBODIED TECHNICAL CHANGE

Solow's key assumption of neutrality in technical change equates the ratio of marginal products before and after technical change and corresponds to Hicks' definition of neutrality measured along a constant capital-labor ratio. There are two alternative definitions, each developed for the specific issues addressed (Allen, 1967). Harrod focused on the requirements for steady state growth and therefore defined neutrality along a constant output-capital ratio, where neutral technical change is labor-augmenting; $Q = F(K, A(t)L)$. Solow later offered his own brand of neutral technical change, defined along a constant output-labor ratio as capital-augmenting to fit his vintage model ; $Q = F(A(t)K, L)$. Hicks' measure is designed to capture the complex effects of innovations on relative factor prices and the substitution induced by these innovations (Blaug, 1985).

Beginning with

$$Q = A(t)f(K,L)$$

Solow differentiates with respect to time and divides by Q,

$$Q' = A'(t) + A(t)\ \partial f/\partial K\ (K'K)/Q + A(t)\ \partial f/\partial L\ (L'L)/Q$$

equates factor shares with factor elasticities (i.e., $A(t)\ \partial f/\partial K = \partial Q/\partial K$ and $A(t)\ \partial f/\partial L = \partial Q/\partial L$), and rearranges terms

$$Q' = A'(t) + \partial Q/\partial K\ (K'K)/Q + \partial Q/\partial L\ (L'L)/Q$$

Under the first order conditions for profit maximization, a factor's output elasticity (which is not observed) is equal to its share in Q

$$\theta_x = \partial Q/\partial X\ (X/Q) = w_X X/pQ$$
$$\text{given } \partial Q/\partial X = w_X/p \qquad \text{(first order conditions)}$$

where θ_x *= output elasticity of factor* $X = K, L$
w_X *= factor price of* X
p *= output price*

to derive the familiar equation in which the rate of growth in output is decomposed into the rate of disembodied technical change A' and the rate of growth of the factors.

$$Q' = A' + \theta_K K' + \theta_L L'$$

where the prime notation denotes rate of growth , i.e., $A' = (dA/dt)/A$

Soon after Solow, Salter (1966) was the first to focus on disaggregation to capture structural change as resources shift across sectors. Salter is given credit for attempting to isolate systematically and comprehensively the various influences captured by the residual--returns to scale as well as the neutrality, bias, and substitution effects of changes over time in best-practice techniques in individual industries (Brown, 1966,pp. 105-108). However, his measures are similarly confounded by the interdependence of the technical characteristics of production and movements in relative prices described above. More recent efforts attempt to account for the effects of resource reallocation accompanying structural change. For example, Syrquin (1984, p. 80) shows that aggregate TFP growth (A') is equal to an average of the sectoral TFP rates plus terms that pick up the sectoral reallocation effects of capital and labor

$$Q' = \Sigma\rho_i\theta^i_K K'_i + \Sigma\rho_i\theta^i_L L'_i + \Sigma\rho_i A'_i$$

where $\rho_i = Q_i/Q$ *= output share of sector i*
θ^i_X *= output elasticity of factor X in sector i*

This formulation takes explicit account of the shifts in resources that occur with structural change. It extends the growth accounting work by Kuznets (1966), the adjustments to traditional TFP by Denison (1962), and builds upon Chenery's focus on disaggregated analysis. Such analysis has become an important contribution to traditional neoclassical methods which assume long-run equilibrium.

VINTAGE MODEL OF EMBODIED TECHNICAL CHANGE

After assuming disembodied technical change, Solow recognized the problem of assuming homogeneous and malleable capital which evades the whole issue of aggregation by ignoring the differing productivities of different vintages of capital goods. As Harcourt (1972, p.48) explains, it is as though

> "at any moment in time, all existing capital goods could be costlessly and timelessly changed into the latest cost-minimizing form as indicated by expectations of future product and relative factor prices...Thus disembodied neutral technical progress may be likened to a mysterious manifestation of grace--when...capital and labor, are gathered together in this life, there immediately occurs a rise of considerable dimensions in total factor productivity."

The problem of aggregation with respect to capital was dramatized by the debate with Joan Robinson over the possibility of constructing a quantity index of capital. Robinson argued that such an index had to be independent from the distribution of the product and relative prices; only then could it be legitimately used to analyze the distribution of the product given that the amount and rate of profits are determined by the technical characteristics of production.

Solow's (1959) vintage model accommodates both embodied and disembodied technical change to account for the heterogeneity and durability of capital. Like most vintage models, vintage or age determines the productivity of capital with the latest vintage capital embodying the most advanced and productive technology. These models highlight the importance of the rate of investment on the rate of technical change by assuming that each vintage of capital represents the gross investment for that period. Similarly, each vintage represents the choice of ex-ante production and substitution possibilities given relative factor prices and demand conditions at the time of the investment decision. The assumptions vary regarding factor substitutability before and after the installation of new machinery, with most neoclassical versions allowing some ex-post substitution. There are three types of vintage models categorized by the combination of assumptions on ex-ante and ex-post substitutability between labor and capital. Putty-putty models allow substitution before and after the installation of new capital equipment. Clay-clay models assume fixed factor proportions in both instances while most mixed models allow only ex-ante substitutability. For the latter, the assumption of infinite capital is replaced by the determination of obsolescence.

Solow's (1959) model defines output at a given time as the integral over the output of existing vintages and their labor requirements together with a shift factor to account for disembodied technical change. Solow's vintage model is

$$Q(t) = Ae^{(\gamma - \delta\beta)t} L(t)^{\alpha} \left[\int_{-\infty}^{t} e^{(\delta + \lambda)v} I(v)dv\right]^{\beta}$$

where A = shift factor

I(v)= gross investment of vintage v in year t

γ = rate of disembodied technical change

δ = rate of depreciation

λ = rate of embodied technical change

α = labor share

β = capital share

where the expression in brackets defines capital as a function of gross investment in vintage *v*, depreciated and improved at a constant rate over the economic life of these assets (in this case assumed infinite). Both capital and labor are affected by disembodied neutral technical change. As Nadiri (1970, p. 1144) notes, conditions for aggregation over heterogeneous capital inputs require that the rate of substitution between them to be independent of the quantity of labor used with them. Moreover, the condition for aggregation over heterogeneous production units even with homogeneous capital further requires technical change to be capital-augmenting. These are basically the conditions postulated by Solow in this model.

However, the empirical problems involved in identifying the parameters--the rates of embodied and disembodied technical change and of depreciation, and the factor shares--

have limited the model's application. Solow's results (re-establish the importance of capital accumulation underestimated by his previous effort) are inconclusive due to their sensitivity to the method of estimation and the data utilized (Nadiri, 1970, p. 1162). This has limited empirical applications particularly in LDCs where data constraints are greater.

Moreover, growth theory has turned to general equilibrium models of these economies claiming an ability to better capture the complex interdependencies among variables (e.g., Kelley and Williamson, 1973). These claims are justified in principle, but these models have gotten us no closer to understanding the black box of production and technological progress. In addition, there have been other approaches to modelling the link between technical change and investment. For example, the models of Arrow (1962) and Kaldor and Mirrless (1962) mark a move away from the traditional notion of the production function. Their focus is on modelling the production of capital goods as a function relating inputs to a cumulative index of activities, in terms of cumulative output or time spent. These models have been little used in applied work.

APPENDIX B

STOCHASTIC FRONTIERS

Stochastic frontiers are the most theoretically advanced but the least applied of efficiency measurement techniques. They explicitly account for statistical noise providing analysts the basis for hypotheses testing. Following Schmidt (1985, p. 303), in the typical stochastic model output is bounded from above by a stochastic production function

$$y_s = A + \Sigma_i x_{si} + v_s - u_s \qquad\qquad u_s \geq 0$$

where v_s is the random component and satisfies the usual normality assumption. The challenge in this type of frontier is the treatment of the nonnormal error we assume captures technical efficiency. In order to estimate this model, analysts usually assume that v_s, u_s, and x_{si} are mutually independent and specify a distribution for u_s. The most popular distribution is the half-normal though, as Schmidt (1985, p. 305) notes, "for no reason that is readily apparent" although the exponential distribution is also used. The next step is to estimate MLEs by maximizing a likelihood function whose derivation can be intractable. Alternatively, the model can be estimated using OLS and then "correcting" the constant term with a consistent estimator of $E(u)$ based on the higher moments of the least squares residuals.

These estimation procedures yield an estimate for $(v_s - u_s)$, and we face the problem of distinguishing u_s from this composite error term. $E(u)$ can be estimated consistently, but provides a measure of mean technical efficiency for the sample. In order to get firm specific TEIs, some analysts such as van den Broeck (1988) have applied a procedure based on the conditional distribution of u_s given $(v_s - u_s)$, *i.e.*, $E(u_s/v_s - u_s)$ evaluated at the estimated values of $(v_s - u_s)$ and the parameters. Schmidt (1985, p. 308), however, considers the fact that "the separation of noise and inefficiency ultimately hinges on strong (and arbitrary) distributional assumptions" as the most serious problem of stochastic frontiers.

This problem can be avoided when panel data are available by resorting to a fixed-effects model in which firm technical inefficiency (u_s) is time invariant

$$y_{st} = \alpha_s + x_{st}\beta + v_{st} - u_s$$

where v_{st} = *random error component*
u_s = *technical efficiency component*

The fixed-effects model overcomes three important problems of frontier models. First, we get around the problem of having to make distributional assumptions regarding v and u. Second, we need not assume that the x_{st} are uncorrelated with u_{st}. Rather than assume that managers make production decisions without prior knowledge of stochastic components, we can argue that firms can anticipate technical inefficiency and this may well effect their decisions. Thus, we need not assume all inputs are exogenous and uncorrelated with the error term.

Third, the problem of distinguishing u_s from $(v_s - u_s)$ becomes manageable since with panel data we have T rather than just one observation for u_s. In sum, then, the advantage of the fixed effects model is its requirement for a minimal set of assumptions. This advantage, however, is traded off against the assumption that firm effects are constant over time. The estimation procedure guarantees this; the first step is to transform the data into deviations from group means ridding the model of time invariant variables. We can then apply OLS to the transformed data to derive the "within group" or fixed effects estimators for $\hat{\beta}$. For example, Hsiao (1985, p. 137) shows that the transformed model becomes

$$y_{st} - y_s = \beta(x_{st} - \underline{\underline{x}}_s) + (v_{st} - \underline{\underline{v}}_s)$$

where group means are denoted with the double underline i.e., $\underline{\underline{x}}_s = \Sigma_t x_{st}/T$
$t = 1,...,T$

A recent application of the fixed-effects model with panel data in the context of technical efficiency is the work by Seale (1985). He builds upon the seminal work by Hoch (1962), using a joint estimation of a Cobb-Douglas production function and share equations to derive unit-specific TEIs, but normalizes these measures relative to the frontier firm rather than the average. Using the "within" estimator, he treats individual firm effects as fixed implying different intercepts but the same slope coefficients for each firm (to avoid having to make distributional assumptions about the composed error term). Seale's production function is:

$$ln\ y_{st} = a_1 ln\ L_{st} + a_2\ ln\ K_{st} + d_s + v_{st}$$ *where d_s are the individual firm efficiency measures*

Postulating that entrepreneurs maximize expected profits (thereby making output endogenous) and that they can sell their output without affecting its price, he derives factor demand equations from the first order conditions for profit maximization to create a system of K+1 equations (where K refers to the number of variable factors). Seale's work focuses on the Egyptian cement tile industry, which presents clear advantages in terms of the homogeneity of its output (basically colored and non-colored tiles). The author is able to gather quantity data and so avoids the problem of estimating the production frontier from monetary values. The problem of aggregation across firms in also avoided, but that of labor and capital inputs remain. Seale aggregates labor hours according to a scheme categorizing workers by activity that he claims roughly coincides with wage-weighting. Using incomplete data on machine hours along with data on the number of machines by type, quantities and prices of some raw materials purchased, he derives a proxy variable for machine hours. Output is measured in square meters and aggregation is value weighted.

Seale (1985) finds that technical efficiency is related to size. Inefficient firms tend to be too small reflecting the various restrictions on the availability of capital in Egypt. Given an increasing population, the industry faces increasing demand and is in the process of adjusting to meet it. The overall policy implications are clear--a removal of restrictions on capital would allow firms to grow and operate at a more efficient scale than before--if we accept that technical efficiency is time invariant over the two and a half years covered by the study. Despite the disaggregated level of this study, Seale (1985) does not support his conclusion with examples of the problems of capital availability faced by his firms. Other than citing differential access between rural and urban firms, his study offers no insights into the specific problems faced by his 25 firms.

Cornwell, Schmidt, and Sickles (1988, henceforth CSS) extend the application of the "within" estimator. To exploit the advantages of panel data without having to assume technical efficiency is time invariant, the u_s are replaced by a flexible (in this case, quadratic) function of time whose parameters vary across firms

$$u_{st} = \theta_{s1} + \theta_{s2} + \theta_{s3}t^2$$

This function captures productivity growth, whose rate varies across firms such that levels of firm inefficiency are allowed to vary over time (CSS, 1988, p. 1). Specifically, the time derivative of u_{st} provides an estimate of TFP growth.

A firm's efficiency level for a given time period is calculated by comparing the firm's actual output to the frontier level--the production function of the most efficient firm, the one with the highest intercept in the u_{st} equation above. The CSS model is defined as

$$y_{st} = x_{st}\beta + w_{st}\delta_s + v_{st}$$
$$\text{where } w_{st} = [1,t,t^2]$$
$$\delta_s = [\theta_{s1} + \theta_{s2} + \theta_{s3}]$$

With this specification CSS measure efficiency by the cross-sectional variation and productivity growth from the variation across time. In the case of time invariant technical efficiency, the typical stochastic model will yield residuals given by $(y_{st} - x_{st}\hat{\beta})$ which are an estimate of $(v_{st} - u_s)$. To estimate firm technical inefficiency, the residuals are averaged over time. In the CSS model with efficiency varying over time, the procedure is similar. To estimate δ_s these authors regress the residuals for firm s on w_{st} to provide an estimate of u_{st} that is consistent. They calculate relative efficiency levels (assuming output is measured in logarithms) in percentage terms with respect to the most efficient firm from

$$RTEI_{rt} = max(\hat{u}_{st}) - \hat{u}_{rt} \qquad r = 1,\ldots,S \qquad for\ r \neq s$$
$$s = 1,\ldots,S,\ t = 1,\ldots,T$$

CSS estimate their model using quarterly data (T = 48) for eight airline companies (S = 8) and specifying a special case of the translog

$$ln\ Q = ln\alpha_0 + \alpha_K ln\ K + \alpha_L ln\ L + \alpha_E ln\ E + \alpha_M ln\ M + \Sigma_s Seasons_s + \Sigma_s ln\ Attribute_s + \Sigma\Sigma_{s \leq r} ln\ Attribute_s\ Attribute_r$$

where Q = *available ton miles*
L = *number of employees*
E = *quantity of energy consumed*
M = *quantity of materials consumed*
Seasons = indexed from winter through summer
Attributes = average stage length, service quality index.

in which outputs and inputs are expressed as Tornqvist indices. This functional form assumes that the average technology is given by a first-order approximation in the logarithms of inputs, and a second-order approximation in the logarithm of output attributes. When CSS attempted to introduce second-order terms for the inputs, they were unable to obtain unique parameter estimates given the almost perfect collinearity in the moment matrix (CSS, 1988, p. 34). They chose not to impose further structure on the model by adding first-order conditions in order to increase the degrees of freedom. This functional form, nonetheless, follows Schmidt's preference for incorporating directly into the production function those factors believed important.

In order to incorporate time varying technical efficiency, CSS apply the Hausman and Taylor (1981) suggestion of identifying those elements of x_{st} correlated (endogenous) and uncorrelated (exogenous) with the u_s. and using the uncorrelated elements as instrumental variables to derive unbiased estimates of the βs. According to Hausman and Taylor (1981, p. 1384), "because the only component of the disturbance which is correlated with the explanatory variables is time-invariant, any vector orthogonal to a time-invariant vector can be used as an instrument." The authors assume capital (K) and energy (E) are correlated with the u_s and labor (L) and materials (M) are considered exogenous. A rational expectations interpretation of contract signing, applicable to the airline industry, provides a rationale for assuming managers consider the labor input as given. Changes in input usage during the quarter will likely involve changes in hours worked not in number of employees, which is used as the labor input variable. The material input is derived as a residual category including various types of goods and services. Because CSS construct the Tornqvist quantity index for materials using a variety of price deflators and aggregate price indices, the chances of their correlation with changes in efficiency in the airline industry are reduced, barring monopsonistic behavior by the firms.

The authors' testing procedures supports these exogeneity assumptions. CSS applied the Hausman-Wu statistic based on the differences between the within and their efficient instrumental variables (IV) estimates. Comparing the results from within group, their efficient IV, and generalized least squares estimators, the authors found that the first two are very similar, but the second is slightly more precise.

APPENDIX C

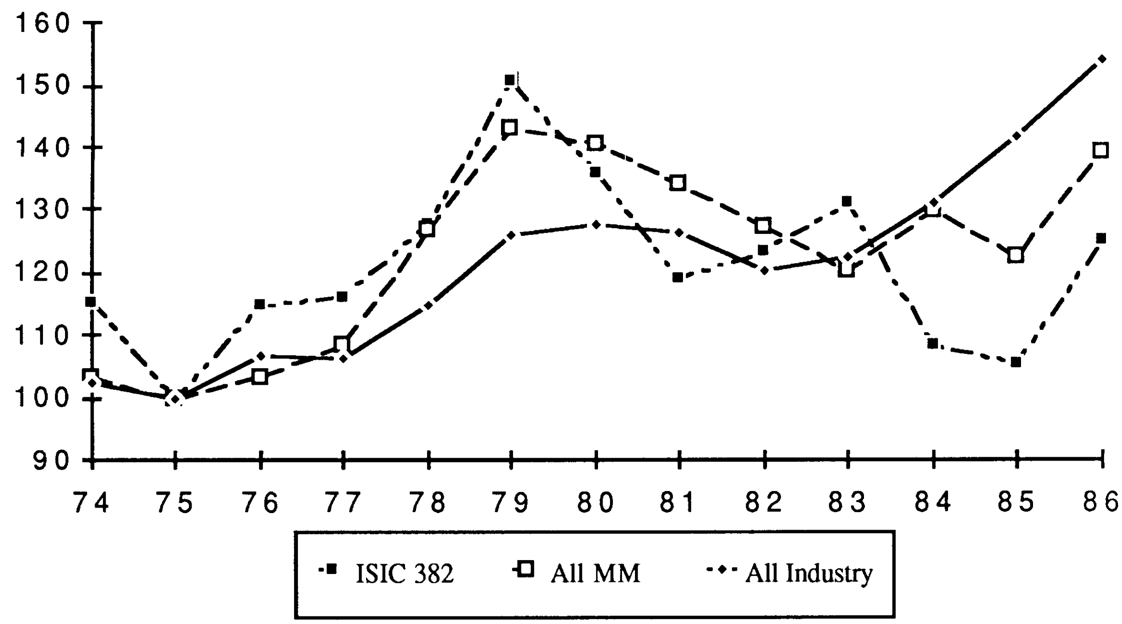
SUPPLEMENTARY TABLES AND CHARTS

CHAPTER 4

CHART 4A.1

REAL GROSS OUTPUT FOR NONELECTRICAL MACHINERY (ISIC 382), METAL-MECHANICAL SECTOR (MM), AND ALL INDUSTRY: 1974-1986

(1975=100)



Sources: Banco de La República (BdlR) for all industry real output; Metal-mechanical output is the sum of the deflated outputs (using their respective wholesale price index from BdlR applied to current price data from DANE's *Encuesta Manufacturera*) for: metal products (381), nonelectrical machinery (382), electrical machinery (383), transport equipment (384), and scientific instruments (385).

TABLE 4.A.1

REAL AND EFFECTIVE EXCHANGE RATES PESO/DOLLAR 1975-1986

(percent)

Year	Nominal Exchange Rate (NER)	CPI Blue Collar (COL)	Ratio US to Colombian Inflation (US/COL)	Real Exchange Rate (RER)	Effective Export Subsidy (EES)	Real Effective Exchange Rate (REER)
1975	100.0	100.0	1.00	100.0	6.7	106.7
1976	112.2	125.7	0.85	95.4	6.5	101.6
1977	117.9	161.3	0.73	85.7	8.1	92.6
1978	125.3	191.6	0.68	85.5	9.6	93.7
1979	136.5	246.7	0.60	81.7	11.7	91.3
1980	151.6	310.7	0.55	83.5	13.3	94.6
1981	174.7	392.7	0.47	81.6	7.2	87.5
1982	205.4	487.2	0.37	75.6	7.7	81.4
1983	252.9	568.2	0.29	73.6	12.3	82.7
1984	323.1	672.0	0.25	79.9	14.5	91.5
1985	456.1	822.8	0.20	91.4	14.4	104.6
1986	628.5	995.6	0.17	108.5	8.7	117.9

RER = NER(US/COL) - measures the extent to which the rate of peso devaluation offsets differences between the rate of inflation in Colombia (COL) and its main trading partners (US); REER = RER + RER(EES) - incorporates the effects of export subsidy incentives.

Data sources: Banco de La República data except for the EES column from the World Bank (1983, p.185).

TABLE 4A.2

STRUCTURE OF PROTECTION IN SELECTED YEARS BY BROAD PRODUCT CLASSES

Mean and Standard Deviations (s.d.) in percent

Period/	February 1979			December 1979			December 1984			December 1985			December 1986		
Import Item	NP	EP	PL	NP	EP	PL	NP	EP	PL	NP	EP	PL	NP	EP	PL
Consumer	43	87	48	39	81	32	66	139		46	93			72	
s.d.	22	50		22	49		37	120		16					
Intermediates	22	32	43	20	29	28	22	25		18	22			55	
s.d.	11	21		10	18		15	48		10					
Metal Product	40	67	46	36	59	41		100			76			65	
s.d.	11	27		10	25										
Nonelec.Mach	24	29	49	22	28	46	31	40		25	25			47	
s.d.	19	29		18	28										
Electric Mach	34	53	52	32	50	52		75			51				
s.d.	18	38		16	34										
Transport Eq.	37	82	73	34	75	70	42	100		31	49			65	
s.d.	40	102		34	91		45	155		28	87				
Total	28	48	46	26	43	33	42	71	83	31	52	72		64	63
s.d.	19	43		18	40		30	89		16	53			59	
Actual tariffs levied:															
Nonelec.Mach					27			29			31				
Total				22	43		20	36		20	37				
s.d.					50			60			63				

NP=Nominal rate of protection; EP=Effective rate of protection and takes into account the nominal protection accorded to intermediate products; these represent theoretical tariffs, actuals levied for selected items are shown in the bottom two rows of this table; PL=percentage of items requiring prior license as opposed to those in free or the seldom used prohibited import list; Nonelec.Mach=Nonelectrical Machinery (ISIC 382); Electric Machinery (ISIC 383), and Transport Eq.= Transport Equipment (ISIC 384).

Sources: 1979 data come from World Bank, 1983, p.193; 1984 data from Cubillos and Torres, 1987, pp.78-82; 1985 data from *Coyuntura Económica*, 1986, pp.57-62 and Ospina, 1988, pp.48-49b; 1986 data from World Bank, 1987, pp.31-32 and refers to 22 national accounts sectors such that these EPs are not directly comparable to other years estimates based on import chapters.

TABLE 4A.3

TRENDS IN GROSS FIXED CAPITAL FORMATION (GFCF): 1975-1986

(percent)

Year	Annual Rates of Growth in Total GFCF	Annual Rates of Growth in Machinery	Machinery share of GFCF	Imports as Share of all Machinery
1975	-3.8	-3.5	31.8	59.7
1976	9.5	4.4	30.4	63.3
1977	0.7	1.9	30.8	63.8
1978	9.3	15.7	32.6	66.3
1979	3.8	7.8	33.8	68.2
1980	13.2	16.6	34.9	74.4
1981	6.3	7.1	35.2	78.4
1982	3.0	-0.6	33.9	82.6
1983	1.2	0.9	33.9	82.9
1984	1.2	-3.2	32.4	80.6
1985	-5.2	-18.7	27.8	77.9
1986	8.1	25.7	32.2	80.7

Sources: Banco de La República and National Accounts data.

TABLE 4A.4

CHANGES IN PRICES BETWEEN SURVEY YEARS 1977 AND 1986

(percent)

Industry Group/ Price Index	Average 1975-76	1977	Average 1984-85	1986	1977-1986 Average	1977-1986 s.d.
GDP Deflator	24.2	29.1	24.0	22.7	23.5	3.4
ISIC 382	24.5	25.6	37.3	19.9	24.6	8.1
CPI Blue Collar	21.8	34.8	20.5	20.7	24.5	5.2
Capital Goods	23.1	18.1	29.4	24.3	23.2	4.3
Intermediates	22.2	10.6	21.3	26.6	20.2	4.9

s.d.=standard deviation; ISIC 382 corresponds to nonelectrical machinery. Unless otherwise specified all indices are wholesale price indices; capital goods includes construction as well as machinery and equipment.

Data sources: Banco de la República's *Revista del Banco de la República*.

CHAPTER 5

TABLE 5A.1

TECHNICAL EFFICIENCY INDICES (TEI) BY YEAR, INDUSTRY, AND FIRM SIZE: UNWEIGHTED PERSON DAYS

Means and Standard Deviations (s.d.) in percentages with respect to the best-practice frontier

Year/ TEI Measured with	All Firms	Industry		Number of Employees		
		Agricult.	Kitchens	1-20	21-40	41+
1977:						
p_K-LPD	49	56	38[b]	51	42	52
(s.d.)	(26)	(22)	(28)	(27)	(24)	(26)
p_{vt}-LPD	50	52	47	48	48	55
(s.d.)	(26)	(23)	(31)	(28)	(23)	(27)
1986 (current pesos):						
p_K-LPD	59[c]	58	57	63	51	64
(s.d.)	(25)	(27)	(22)	(23)	(21)	(33)
p_{vt}-LPD	58	56	56	64	51	53
(s.d.)	(26)	(28)	(23)	(20)	(24)	(36)
Changes **1977-1986**:						
p_K-LPD	4	-4	13[c]	3	6	3
(s.d.)	(26)	(27)	(22)	(29)	(25)	(28)
p_{vt}-LPD	-1	-5	20	4	-3	-5
(s.d.)	(29)	(32)	(27)	(33)	(28)	(29)

Agricult.: agricultural implements; kitchens: kitchen equipment; p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LPD: labor in person days. Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level.

TABLE 5A.2

COMPARISON OF CBI AND OWN INPUT, OUPUT, AND OTHER MEASURES

In 1977 current pesos unless otherwise noted

Item	CBI Estimates (N = 65) Mean	CBI Estimates Standard Deviation	Own Estimates (N = 50) Mean	Own Estimates Standard Deviation
Number of employees	33	29	31	25
LUE	20,985	18,684	17,160	13,612
LPD	n.a	n.a	8293	6566
Value Added (000's)	4861	6776	4355	5741
Capital services -p_K	287	390	318	289
Capital services -p_{vt}	n.a	n.a.	568	578
Value Added/LUE	208	115	326	182
Value Added/p_K	23	20	14	14
Firm age (years)	14	11	14	11

N: number of observations or firms in sample; p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LUE: unskilled equivalent labor in person days; LPD: labor in person days. The 15 firms we excluded from the original CBI sample were producers of varied agricultural capital goods including pumps and machinery for post-harvest use.

Source: CBI data from Cortes, Berry, and Ishaq (1987) p. 90.

TABLE 5A.3

CAPITAL LABOR RATIOS BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in pesos

Year/ Item	All Firms	Industry		Number of Employees		
		Agricult.	Kitchens	1-20	21-40	41+
1977:						
p_K/LUE	20	18	24	19	26	16[c]
(s.d.)	(13)	(9)	(18)	(7)	(20)	(11)
p_{vt}/LUE	36	33	40	33	43	33
(s.d.)	(26)	(24)	(29)	(16)	(33)	(30)
1986 (current pesos):						
p_K/LUE	296	315	275	402	248	232[b]
(s.d.)	(149)	(138)	(163)	(163)	(105)	(144)
p_{vt}/LUE	357	347	368	560	254	260[b]
(s.d.)	(303)	(331)	(282)	(434)	(153)	(98)
1986 (constant pesos):						
p_K/LUE	41[a]	44	38	56	34	33[b]
(s.d.)	(22)	(20)	(24)	(24)	(14)	(21)
p_{vt}/LUE	52	48	56	82	40	31[c]
(s.d.)	(51)	(29)	(69)	(77)	(24)	(22)
1977-86 Changes (increment in constant pesos):						
p_K/LUE	20	28	11[b]	21	18	21
(s.d.)	(20)	(16)	(20)	(24)	(19)	(17)
p_{vt}/LUE	18	21	16	14	25	14
(s.d.)	(42)	(34)	(51)	(36)	(51)	(37)

Agricult.: agricultural implements; kitchens: kitchen equipment; p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LUE: labor in unskilled equivalent person days. Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level.

TABLE 5A.4

INPUT CHARACTERISTICS BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in years unless otherwise noted

Year/	All	Industry		Number of Employees		
Item	Firms	Agricult.	Kitchens	1-20	21-40	41+
1977:						
Firm age	14	14	15	14	13	16
(s.d.)	(11)	(11)	(10)	(12)	(8)	(12)
CEO exp.	19	18	20	21	17	17
(s.d.)	(10)	(10)	(10)	(12)	(9)	(8)
Skill Ratio(%)	44	47	40	44	44	44
(s.d.)	(18)	(18)	(18)	(19)	(19)	(17)
Workers exp.	3	3	3	3	3	4[c]
(s.d.)	(2)	(2)	(2)	(2)	(1)	(2)
Vintage-capital	8	8	7	7	7	9
(s.d.)	(4)	(4)	(4)	(3)	(4)	(4)
1986:						
Firm age	21[b]	21	21	24	17	25
(s.d.)	(13)	(15)	(11)	(13)	(9)	(21)
CEO exp.	25[b]	24	26	31	22	22
(s.d.)	(11)	(12)	(11)	(12)	(11)	(9)
Skill Ratio(%)	46	47	44	44	44	55
(s.d.)	(20)	(22)	(18)	(20)	(21)	(16)
Workers exp.	3	3	3	3	3	3
(s.d.)	(1)	(1)	(1)	(2)	(1)	(1)
Vintage-capital	12	13	11	14	12	10
(s.d.)	(5)	(3)	(6)	(4)	(6)	(4)

Agricult.- agricultural implements; CEO exp.: entrepreneur's experience in sector weighted by type of experience--production or administrative in the firm and elsewhere; experience of workers refers to experience in the firm; skill ratio is the ratio of technical and skilled workers to total production workers. Means for given group (by year, industry, and size) are significantly different at the: a- .001 level; b- .01 level; c- .1 level.

TABLE 5A.5

PRODUCTION CHARACTERISTICS BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) as a percentage of output except*

Year/	All	Industry		Number of Employees		
Item	Firms	Agricult.	Kitchens	1-20	21-40	41+
1977:						
Unit by unit	27	20	38	47	15	8[a]
(s.d.)	(39)	(34)	(43)	(42)	(30)	(26)
Main product	52	56	48	53	62	37
(s.d.)	(25)	(26)	(24)	(22)	(31)	(17)
Intermediates	45	48	41[c]	48	39	48[c]
(s.d.)	(14)	(13)	(15)	(15)	(13)	(11)
Subcontracted	3	1	5	1	7	1
(s.d.)	(10)	(3)	(16)	(3)	(19)	(1)
Subcon.Input*	8	8	9	10	2	10
(s.d.)	(10)	(10)	(10)	(10)	(3)	(12)
Exported	5	6	3	1	4	11[c]
(s.d)	(14)	(16)	(9)	(4)	(11)	(22)
1986:						
Unit by unit	24	19	29	35	25	2
(s.d.)	(37)	(33)	(43)	(43)	(38)	(2)
Main product	57	60	56	49	58	64
(s.d.)	(18)	(13)	(20)	(16)	(21)	(15)
Intermediates	39	42	36	43	37	38
(s.d.)	(13)	(13)	(12)	(13)	(14)	(18)
Subcontracted	7	5	9	16	3	0
(s.d.)	(20)	(12)	(27)	(34)	(7)	(0)
Subcon.Input*	8	9	8	7	10	7
(s.d.)	(12)	(11)	(13)	(9)	(14)	(3)
Exported	1[c]	2	1	0	1	5[c]
(s.d)	(4)	(5)	(2)	(0)	(2)	(8)

Agricult.: agricultural implements; kitchens: kitchen equipment; *Subcon. input: percentage of input costs subcontracted from other firms. Means of respective groups (by year, industry, and size) are significant at the: a= .001 level; b-= .01 level;c=.1 level.

TABLE 5A.6

REGRESSION RESULTS: DETERMINANTS OF CAPITAL INTENSITY

Standard Errors in parentheses

Independent Variables	Ln Capital Labor Ratio as dependent variable measured with LUE and:					
	1977		1986		1986 (1977$P)	
	p_k	p_{vt}	p_k	p_{vt}	p_k	p_{vt}
Constant	-3.95[a]	-3.11[a]	0.04	0.60	-1.57[a]	-1.11[a]
	(0.34)		(0.27)	(0.57)	(0.44)	(0.72)
Labor contract	-0.21[c]		-0.22		-0.18	-0.32
(longer-term=1)	(0.16)		(0.18)		(0.17)	(0.27)
Unit-by-unit prdtn.		-0.62[b]		-0.33		
(% of output)		(0.27)		(0.31)		
Skilled Wkr.Ratio		-0.59				-0.66
(% prdction wkrs)		(0.48)				(0.92)
Vintage of capital	-0.20	-0.25				
(ln of years)	(0.14)	(0.17)				
Labor cost problem	0.63[b]	0.72[b]				
(yes=1)	(0.23)	(0.26)				
Capital problem			0.13	-0.95[b]		
(yes=1)			(0.21)	(0.25)		
Capacity utilization			-1.67[a]	-1.96[a]	-1.73[a]	-2.08[a]
(%)			(0.38)	(0.50)	(0.39)	(0.63)
Employees		0.17				
(ln of number)		(0.11)				
$ATRR_{vt}$		0.09[b]				
(%)		(0.03)				
Subcont. inputs	-1.24[c]	-1.51[c]				
(% input costs)	(0.72)	(0.86)				
Design/Engineering			-0.81	-0.64	-0.92[c]	-1.43
(% of top score)			(0.52)	(0.67)	(0.52)	(0.89)
R^2 adjusted	0.18	0.23	0.44	0.50	0.44	0.32
N (observations)	50	50	26	26	26	26
F	3.68[b]	3.43[b]	5.90[a]	7.32[a]	7.46[a]	3.89[b]

Ln: natural logarithm; p_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow; LUE: labor in unskilled equivalent person days; 1977$P: constant 1977 pesos; Regression coefficients are significant at the: a= .001 level; b= .01 level; c= .1 level.

TABLE 5A.7

FINANCIAL CHARACTERISTICS BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in percentages

Year/	All	Industry		Number of Employees		
Item	Firms	Agricult.	Kitchens	1-20	21-40	41+
1977:						
Direct Sales	60	55	68	85	51	31[a]
(s.d.)	(40)	(40)	(40)	(24)	(38)	(41)
Sales on credit	62	67	54	56	71	63
(s.d.)	(34)	(34)	(35)	(36)	(26)	(39)
Mat. on credit	52	46	61	40	77	44[b]
(s.d.)	(40)	(47)	(31)	(39)	(31)	(42)
Output in stock	5	5	5	6	7	1
(s.d.)	(12)	(14)	(10)	(15)	(11)	(1)
Mat. in stock	13	13	14	11	11	21[c]
(s.d.)	(15)	(12)	(19)	(13)	(6)	(21)
Fringe Benefit	37	37	37	31	38	45[a]
(s.d.)	(11)	(10)	(13)	(11)	(6)	(11)
1986:						
Direct Sales	53	55	51	63	55	32
(s.d.)	(37)	(35)	(41)	(43)	(35)	(31)
Sales on credit	59	74	41[b]	49	60	72
(s.d.)	(35)	(35)	(26)	(40)	(31)	(36)
Mat. on credit	54	46	63	35	63	66
(s.d.)	(45)	(45)	(44)	(48)	(42)	(41)
Output in stock	29[c]	40	17	50	21	10
(s.d.)	(61)	(83)	(23)	(104)	(21)	(11)
Mat. in stock	20[b]	20	20	15	23	20
(s.d.)	(13)	(14)	(14)	(10)	(15)	(14)
Fringe Benefit	44	48	40	34	46	56[b]
(s.d.)	(16)	(17)	(14)	(16)	(4)	(25)

Agricult.: agricultural implements; kitchens: kitchen equipment; Output and materials in stock are expressed as a percentage of total output; fringe benefits are expressed as a percentage of the basic wage. Means for given group (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level.

TABLE 5A.8

1977-1986 CHANGES BY INDUSTRY AND FIRM SIZE

Means and Standard Deviations (s.d.) in percent

Changes in	All Firms	Industry		Number of Employees in 1977		
		Agricult.	Kitchens	1-20	21-40	41+
TEI based on:						
p_K-LUE	3.6	-5.4	13.3[c]	10.7	8.1	-9.7
(s.d.)	(29.9)	(26.2)	(31.5)	(31.4)	(33.2)	(21.4)
p_{vt}-LUE	0.3	-6.5	7.7[c]	3.2	4.2	-7.8
(s.d.)	(23.8)	(27.0)	(18.1)	(25.5)	(24.1)	(22.8)
Capital-labor Ratio:						
p_K/LUE	153.4	206.7	96.0[c]	121.7	142.6	200.0
(s.d.)	(161.9)	(163.7)	(144.6)	(126.5)	(139.2)	(223.4)
p_v/LUE	91.9	138.0	42.3[b]	71.0	82.7	125.6
(s.d.)	(124.6)	(136.8)	(90.6)	(135.0)	(101.7)	(150.7)
Pooled TEI based on:						
p_K-LUE	3.2	5.6	0.5	0.2	0.5	9.6
(s.d.)	(21.9)	(23.5)	(20.6)	(25.8)	(12.7)	(28.6)
p_{vt}-LUE	4.0	9.0	-1.4	4.7	0.7	7.9
(s.d.)	(22.2)	(25.5)	(17.9)	(27.4)	(16.1)	(26.5)
Other Variables:						
Employees	0.6	-9.2	11.1	49.4	-13.3	-29.1[b]
(s.d.)	(61.7)	(52.7)	(70.8)	(84.1)	(28.2)	(43.5)
Real sales	-2.7	-17.8	13.6	4.2	-4.0	-7.8
(s.d.)	(70.3)	(49.7)	(86.5)	(59.2)	(64.2)	(94.3)

Agricult.: agricultural implements; kitchens: kitchen equipment; p_K: aggregate measure of capital flow; LUE: labor in unskilled equivalent person days; p_{vt}: disaggregated measure of capital flow; pooled TEIs identify frontier firms over both years. Means of respective groups (by year, industry, and size) are significantly different at the: b= .01 level; c= .1 level.

TABLE 5A.9

TECHNICAL EFFICIENCY INDICES (TEI) BY YEAR, INDUSTRY, AND FIRM SIZE: PRICE-QUALITY COMPARABILITY*

Means and Standard Deviations (s.d.) in percent with respect to the best practice-frontier

Year/ TEI	All	Industry		Number of Employees		
Measured with	Firms	Agricult.	Kitchens	1-20	21-40	41+
1977:						
p_K-LUE	53	63	38[a]	52	42	66[c]
(s.d.)	(29)	(25)	(30)	(33)	(22)	(27)
p_{vt}-LUE	51	64	32[c]	51	39	64[c]
(s.d.)	(30)	(25)	(27)	(31)	(26)	(28)
1986 (current pesos):						
p_K-LUE	63[b]	60	65[x]	72	54	66
(s.d.)	(25)	(30)	(20)	(25)	(24)	(27)
p_{vt}-LUE	59	54	65[x]	54	61	63
(s.d.)	(24)	(27)	(20)	(23)	(23)	(32)
1986 (constant pesos):						
p_K-LUE	55	53	57	58	47	68
(s.d.)	(24)	(25)	(24)	(26)	(20)	(30)
p_{vt}-LUE	57	58	56	61	51	67
(s.d.)	(25)	(27)	(24)	(26)	(23)	(30)
1977-86 changes:						
p_K-LUE	4	-12	21[b]	7	17	-18[c]
(s.d.)	(33)	(29)	(28)	(32)	(29)	(31)
p_{vt}-LUE	5	-18	29[a]	0	25	-19[b]
(s.d.)	(36)	(33)	(22)	(35)	(23)	(40)
1977 Pooled:						
p_K-LUE	41	47	31[b]	42	32	46
(s.d.)	(25)	(20)	(29)	(27)	(18)	(27)
p_{vt}-LUE	37	42	28[c]	39	27	44
(s.d.)	(25)	(21)	(29)	(29)	(16)	(23)
1986 Pooled:						
p_K-LUE	42	54	30[b]	46	34	58
(s.d.)	(29)	(28)	(27)	(36)	(19)	(38)
p_{vt}-LUE	42	53	31[c]	42	36	59
(s.d.)	(32)	(27)	(33)	(36)	(26)	(38)

*Price-quality comparability is derived from adjustment of value added based on technical competence scores and the entrepreneur's own evaluation. Agricult.: agricultural implements; kitchens: kitchen equipment; p_K: aggregate measure of capital flow; LUE: labor in unskilled-equivalent person days; p_{vt}: disaggregated measure of capital flow. Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level. Means by industry by year are significantly different at the: x= .001 level.

TABLE 5A.10

TECHNICAL EFFICIENCY INDICES (TEI) BY YEAR, INDUSTRY, AND FIRM SIZE: FULL CAPACITY

Means and Standard Deviations (s.d.) in percentages with respect to the best-practice frontier

Year/ TEI Measured with	All Firms	Industry		Number of Employees		
		Agricult.	Kitchens	1-20	21-40	41+
1977:						
p_K-LUE	51	53	48	48	48	60
(s.d.)	(29)	(27)	(33)	(33)	(25)	(27)
p_{vt}-LUE	52	55	48	48	48	63
(s.d.)	(30)	(27)	(34)	(34)	(23)	(27)
1986 (current pesos):						
p_K-LUE	55	61	51	50	55	68
(s.d.)	(28)	(27)	(29)	(29)	(26)	(32)
p_{vt}-LUE	63[c]	67	55	64	59	65
(s.d.)	(26)	(24)	(26)	(26)	(24)	(33)
1986 (constant pesos):						
p_K-LUE	56	61	51	59	53	61
(s.d.)	(25)	(24)	(25)	(26)	(24)	(27)
p_{vt}-LUE	54	57	52	57	51	58
(s.d.)	(26)	(25)	(25)	(27)	(22)	(31)
1977-86 Changes:						
p_K-LUE	-4	-4	-3	-2	-3	-7
(s.d.)	(25)	(29)	(21)	(30)	(22)	(28)
p_{vt}-LUE	0	0	1	15	1	-15
(s.d.)	(34)	(32)	(38)	(43)	(23)	(35)
1977 Pooled:						
p_K-LUE	39	46	29[b]	42	33	41
(s.d.)	(26)	(25)	(25)	(28)	(24)	(26)
p_{vt}-LUE	38	44	29[b]	40	32	40
(s.d.)	(25)	(24)	(25)	(28)	(21)	(25)
1986 Pooled:						
p_K-LUE	45	45	44[z]	42	43	54
(s.d.)	(24)	(24)	(26)	(27)	(22)	(28)
p_{vt}-LUE	50[c]	55	44[z]	46	48	62
(s.d.)	(25)	(25)	(25)	(29)	(23)	(31)

Agricult.: agricultural implements; kitchens: kitchen equipment; p_K: aggregate measure of capital flow; LUE: labor in unskilled equivalent person days; p_{vt}: disaggregated measure of capital flow. Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level. Means by industry by year are significantly different at the: z= .1 level.

TABLE 5A.11

PRICE-QUALITY CORRECTION FACTORS BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in percentages

Year/ Basis of Quality Premia	All Firms	Industry		Number of Employees		
		Agricult.	Kitchens	1-20	21-40	41+
1977:						
CEO estimates	1.2	1.1	1.3	1.4	1.1	1.1[b]
(s.d.)	(0.4)	(0.2)	(0.6)	(0.5)	(0.1)	(0.3)
Overall Score	1.1	1.1	1.2	1.2	1.0	1.1
(s.d.)	(0.4)	(0.2)	(0.5)	(0.5)	(0.2)	(0.3)
1986:						
CEO estimates	1.1[c]	1.1	1.0	1.1	1.1	1.0
(s.d.)	(0.2)	(0.2)	(0.2)	(0.1)	(0.2)	(0.1)
Overall Score	1.0[b]	1.0	1.0	1.0	1.0	1.0
(s.d.)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)

Agricult.: agricultural implements; kitchens: kitchen equipment; Quality premium= (price-quality adjusted value added/actual value added). Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level.

TABLE 5A.12

CAPACITY UNDERUTILIZATION BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in percentages

Year/ Item	All Firms	Industry		Number of Employees		
		Agricult.	Kitchens	1-20	21-40	41+
1977:						
Capacity Utiliz	78	71	89[a]	70	84	85[c]
(s.d.)	(23)	(23)	(18)	(24)	(20)	(22)
C/B Ratio	90	85	97[b]	88	91	91
(s.d.)	(22)	(27)	(11)	(30)	(15)	(15)
1986:						
Capacity Utiliz	60[a]	60	61	52	61	72
(s.d.)	(21)	(17)	(26)	(18)	(19)	(30)
C/B Ratio	79[a]	82	76	86	73	83
(s.d.)	(29)	(32)	(27)	(40)	(20)	(28)

Agricult.: agricultural implements; kitchens: kitchen equipment; Capacity utilization= (actual value added/full capacity value added); Cost-Benefit Ratio=(full capacity total wage bill/actual total wage bill)/(full capacity value added/value added). Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level.

APPENDIX D

THE COLOMBIAN IMPORT REGIME

Despite the 1984 adjustment program, the import regime remains complex. Import control is exercised by the following mechanisms:

a) The import licensing regime sets the number of import items included in the prohibited, prior license, and free import positions. Prohibited items dropped to less than 2% of the total and free items rose to 36% during 1984-1986. As shown in Table 4A.2 in Appendix C these percentages compare unfavorably with earlier years, but reflect a gradual liberalization in recent years.

b) The tariff structure sets the level and dispersion of tariff rates. The reforms of 1985-1986 sought to reduce the average level of tariffs, their dispersion across tariff positions, and to correct the relative biases between agriculture and industry. Nonetheless, the World Bank regards the 1986 average rate of 51.5% and the variation across individual items from 0 to 200% as high. Moreover, the persistence of a complex system of exemptions (mandated in an ad hoc manner by the executive branch, legislated for government imports and goods destined to free-trade zones, or dispensed by customs officials at their discretion) complicate the picture given by an examination of the statutes alone.

c) The foreign exchange budget controls the resources paid from central bank reserves and allocated for free imports. This budget also sets the guidelines (i.e., with respect to stage of fabrication discriminating raw materials, intermediates, final consumer goods, and capital goods) for distributing the remainder of imports requiring prior license. Non-reimbursable imports paid out of own-funds or included under international agreements, free ports, and special regions are controlled through the discretionary licensing by INCOMEX.[1] This continues to draw criticism from the World Bank because

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[1] Nonreimbursable import requests originate from direct foreign investors, from government and quasi-government importers often using foreign loans, and from Colombians after long stays abroad. Between

the basis for this licensing is past import demands "which in turn reflect past goals regarding the protection of existing Colombian industry" (World Bank, 1987, p. 25).

Although an expansion of the budget has taken place, analysts note the necessity to coordinate the size of this budget--a mechanism to control the balance of payments--with the import licensing regime--a mechanism to guide resource allocation (World Bank, 1987; Coyuntura Económica, 1986). Without such coordination further liberalization of the licensing scheme would be limited by budget constraints to finance imports.

1968-1980 the proportion of nonreimbursables in total registered imports has remained stable at about 13-16% with about 90% of items in this category requiring prior license since 1976. For reimbursables claiming the balance (87-84%) only about half of the items require prior license (World Bank, 1983, pp. 14-15).

TECHNICAL APPENDIX

In this technical appendix we describe the details of the calculations behind our estimates of capital, labor and value added. In light of the challenges in deriving accurate estimates, we performed extensive consistency checks across measures and tested alternative measurement methodologies to examine the robustness of our results. In all cases, as we explain in Chapter 5, we used market prices. In the case of capital we estimated two measures, an aggregated and a more data-intensive disaggregated measure, both based on a peso valuation of the machinery rather than a physical measure of its use, such as machine hours. For the labor input, we estimated two physical measures in terms of person days per year and unskilled labor equivalent days per year. The latter is wage-weighted to account for the differing productivities of labor as reflected in differing wage rates. The value added measure follows traditional accounting practice and is based on aggregate peso valuation of gross output. We will discuss below how we estimated each of these input and output measures as well as detail our treatment of deflation since one of our main objectives in this study is to compare firm performance in 1977 with that of 1986.

With respect to the sources of data presented in tables here and in other chapters, unless otherwise specified, these data refer to our firm sample.

CAPITAL INPUT CALCULATIONS

Most microeconomic studies of technical efficiency start with an aggregate estimate of the cost of replacement of the total capital stock and then annualize it into a capital flow taking into account the years of useful life and the interest rate (see Chapter 5, p. 90). Typically, these studies assume a 10 to 25 year service life and a real cost of capital between 8% and 12%. The Cortes, Berry, and Ishaq (CBI, 1985) study from which our data for 1977 were drawn attempted to more accurately estimate these parameters by considering the actual life (given new or used machinery) and the real interest rate actually applied to the financing of the capital asset (rates varied from 2% to 12% depending on the source--own, public or private bank, supplier/moneylender). An alternative approach is derived from sectoral productivity studies relying on data about the components of the capital stock and the value of transactions on new investment goods. Rather than relying on an aggregate total figure, the components of the capital stock are aged and decayed as time and changes take place. As the reader will note, our calculations for this disaggregated measure draw heavily from Mohr's (1988) extensive survey of capital measurement techniques.

Both approaches recognize that transactions prices are not an appropriate valuation of the flow of capital services derived from a given asset. Capital assets are usually owned and used by the same group and well defined rental markets for components of the capital stock seldom exist (Diewert, 1979; Mohr, 1988). Their real value is related to the return obtained by renting the capital asset. Therefore, when the asset is owner-utilized, the value of the capital services from that asset is called the user cost or rental price. As noted above, in the aggregated approach, this rental price is derived rather mechanically by annualizing the capital stock figure. The disaggregated approach is firmly embedded within the neoclassical theory of production and the assumption of firm optimizing behavior.

Moreover, as we explained in Chapter 2, to avoid the problematic choice of the proper rate of return on capital, either historical or current, we applied Mohr's (1988, p. 126) vintage cost of capital measure (r_{vt}) to reflect the composite historical costs of the mix of vintages in the existing stock as follows

$$r_{vt} = \frac{K^{n}_{0\,t}}{K_t}(r_0 - \pi^e_0) + \frac{\sum_{\tau=0}^{t-2} I^{n}_{\tau\,t}}{K_t}(r_\tau - \pi^e_\tau) + \frac{I^g_{t-1\,t}}{K_t}(r_{t-1} - \pi^e_{t-1}) \qquad (A.1)$$

where

$K^n_{0\,t}$ = *the portion of the historical net stock (subscript n) of capital in place in the beginning of base year 0 and remaining at the beginning of the current year t*

$K_t = K^n_{0\,t} + \sum_0^{t-2} I^n_{\tau\,t} + I^g_{t-1\,t}$ = *net capital stock of old capital at the beginning of year t plus gross investment during year t-1*

r_0 = *truncated cost of capital for vintages purchased before the base year and corresponding to* K_0, *the initial capital stock (as in perpetual inventory models)*

r_τ = *after-tax cost of funds at time* τ

π^e_0 = *expected rate of inflation in output prices*

$I^n_{\tau t}$ = *portion of historical gross investment made in year* τ *still economically useful at the beginning of the current year t*

π^e_τ = *expected rate of inflation in output prices associated with the decision to purchase each vintage of capital from year* $\tau = 0$ *to year t-1*

$I^g_{t-1\,t}$ = *gross investment during year t-1*

Mohr's vintage model charges gross investment the current cost of funds and net capital the historical cost corresponding to respective vintages. It is a weighted sum of the net capital stock and each year's stream of capital investments where the weights are the after tax cost of funds ($r_\tau - \pi_\tau$) at the time of purchase. This formula assures that all costs of capital are decayed through the weighting scheme in which the importance of each vintage's cost of capital decreases with age. This avoids the problem of charging historical capital unreasonable current rates; the recent cost of capital is more important in determining overall opportunity costs.

To apply the above formula, we set 1970 as the base year and *t* to 1977 and 1986 for each survey year, respectively. We chose 1970 as the base year because our pre-1970 interest rate data was incomplete; from 1970 through 1986 we were able to complement our sector and firm specific data with industry-wide data on corporate tax rates gathered by the World Bank (1989). Therefore, the estimates for the after tax cost of funds ($r_\tau - \pi_\tau$ from equation A.1 above) which we used as weights for aggregation of individual assets rely on sector and firm specific data. We used the wholesale price index for the sector (SIC 382) to account for inflationary expectations in the sector's output prices. To account for direct taxation on the cost of capital we estimated the r_τ component as

$$r_\tau = (1-u_\tau)i_\tau$$

where u_τ = *marginal corporate income tax rate at time* τ
i_τ = *pre-tax nominal interest rate (by source of financing) at time* τ

Our assumption that all the firms in our sample were impacted by corporate income taxes is based on our examination of their tax declaration forms which in many cases represented the only documentation available. If we assume smaller firms were less likely to pay taxes, our measure of r_τ may underestimate their cost of capital.

Once we adjusted for inflation ($r_\tau - \pi_\tau$), we encountered the familiar problem of negative real rates particularly when entrepreneurs obtained their financing from development banks which charged them below-market rates. In these cases we followed the Jorgenson and Griliches (1967) practice noted in Chapter 2. We calculated a value for r_τ as the ratio of the non-wage share of value added to the current value of the capital stock. We did not have the year by year data needed to derive firm specific estimates and therefore resorted to an average of the 4-digit SIC aggregates. To reduce the potential biases from resorting to a different methodology we averaged the estimates from the two methods cited.

Following the dictates of index number theory, Mohr further argues that the other components of the rental price of capital formula (not just the cost of capital) should also be weighted averages. Therefore, Mohr rewrites the rental price of capital as

$$p_{vt} = q_{vt}\,(r_{vt} + \delta - \pi_{vt})$$

where

$$q_{vt} = \frac{K^{n}_{0\,t}}{K_t} q_0 + \frac{\sum_{\tau=0}^{t-2} I^{n}_{\tau\,t}}{K_t} q_\tau + \frac{I^{g}_{t-1\,t}}{K_t} q_{t-1}$$

subscripts v and t refer to vintage or age and the current year

This means we calculate, in effect, a linear aggregation of the peso perpetual inventory flows over all vintages for each firm.

In terms of implementing the formula, q_{vt} was given by the entrepreneur and compared across firms to check its reliability. In addition to the asset price, entrepreneurs provided information about the particular asset's service life, and the year of purchase and/or manufacture to determine vintage. In order to avoid the thorny problems of deflation of historical asset prices, we used replacement costs. In 1977, CBI gathered total capital stock estimates at commercial cost ,which together with their shadow price of capital formed the basis for their TEIs. This is reasonable since commercial costs should reflect the asset's historical cost in today's pesos. Unfortunately, commercial costs in 1977 were not provided for individual assets, and we found that some entrepreneurs were less certain of the prices their assets would sell for in 1986 than the costs of replacing them. This reflected changing preferences for new versus second-hand equipment. In 1977 two-thirds of entrepreneurs expressed a preference for new equipment although 60% recognized the cost advantages of second-hand equipment. By 1986 only 15% noted these cost savings.

In many cases, the entrepreneur could not provide a complete disaggregation of the firm's capital assets beyond an estimate of the total capital stock, value of buildings or rent, and information about the main equipment. We assumed that the balance (that is, the difference between the aggregate estimate of the capital stock and the sum of the disaggregated components) had vintage, service life and cost of funds characteristics similar to the weighted average of the disaggregated components. There were only two cases in which this unknown balance represented more than one-half of the firm's total capital stock. These prompted an examination of other corroborative information regarding the firm's capital stock to assure our assumptions were not unreasonable.

Depreciation was estimated as

$$\delta = \frac{\textit{declining balance rate}}{\textit{service life of the asset}}$$

This formula for economic depreciation captures the decline in asset price due to aging. If we were to construct an age-price profile, it would be downward sloping and would shift upwards with inflation. The entrepreneur provided estimates for the denominator. The lack of a subscript shows that we assume a constant rate of depreciation for all assets. This was not the case since we followed Mohr's (1986) suggestion to differentiate between classes of capital assets, in our case between machinery and buildings, and follow the aggregation scheme dictated by index number theory. This transforms Mohr's vintage rental price of capital formula easily to

$$p_{vt} = q_{vt} (r_{vt} + \delta_t - \pi_{vt}) \qquad \textit{where t refers to the type of capital asset}$$

In the case of machinery, the declining balance rate was taken from Hulten and Wykoff's (1981) estimate of 1.65 for metalworking machinery. They derived this figure from their econometric estimation of age-price profiles using a Box-Cox power transformation on US data. Given their estimate of 13.5 for the mean service life of this class of assets, Hulten and Wykoff's figures yield a rate of depreciation of 12.2%.[1]

TABLE A.1

DEPRECIATION RATE AND MEAN SERVICE LIFE (MSL) BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.)

Year/	All	Industry		Number of Employees		
Item	Firms	Agricult.	Kitchens	1-20	21-40	41+
1977:						
MSL (years)	17.0	17.6	16.2	16.8	17.4	17.1
(s.d.)	(4.4)	(3.6)	(5.3)	(4.8)	(3.4)	(4.8)
Depreciation (%)	12.2	12.4	12.0	12.6	11.7	12.1
(s.d.)	(2.8)	(2.5)	(3.3)	(2.8)	(3.1)	(2.7)
1986:						
MSL (years)	17.2	16.7	17.7	17.1	17.7	15.6
(s.d.)	(3.8)	(2.1)	(5.1)	(2.4)	(4.6)	(4.0)
Depreciation (%)	13.0	13.0	13.0	13.3	13.1	12.5
(s.d.)	(2.5)	(2.8)	(2.3)	(2.9)	(2.6)	(2.8)

Agricult.: agricultural implements; kitchens: kitchen equipment.

In the case of buildings, when owned by the firm, we assumed a declining balance rate of 1.5 and a service life of 30 years for buildings, figures confirmed by Hulten and Wykoff. These parameters which yield a depreciation rate of 5% are those assumed by the World Bank for a broad class of capital assets including machinery (World Bank, 1989, p. 143). This contrasts with Roberts (1989) TFP study using plant-level census data whose results we described in the previous chapter. He differentiated two additional types of

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[1] The authors note that their estimate is very close to the BEA (.1278) figure used to estimate net capital stock.

assets, land which does not depreciate, and transport equipment which he depreciates at a faster rate than machinery. Even his rates for machinery (10%) are in no way comparable to those we estimated and presented in Table A.1. As in most studies, his rates are universal rates of depreciation while ours take explicit account of service life which as the cited table shows varies across industries and size of firm.

As shown in Table A.1, mean service life across our sample of 50 firms averaged about 17 years for both 1977 and 1986 with corresponding depreciation rates of 12.2% and 13.0%, respectively. With the higher depreciation rate for 1986 we would expect a lower mean service life given the formula for depreciation. However, this relationship is confounded by the fact that the depreciation rates shown are weighted averages of the two classes of capital assets.

We examined the potential bias introduced by using Hulten and Wykoff's US estimate of the declining balance rate (1.65) with our Colombian data. On one hand, it would seem that this rate would be higher in a developing country such as Colombia. Such a higher rate would tend to yield a higher rate of depreciation and ultimately a higher rental price of capital. Anecdotal evidence suggests that there may be differences in patterns of use. Colombian users tend to be harder on the equipment , in part because operators are less skilled and experienced in its use. This would suggest a more rapid aging of the machinery. On the other hand, the difficulties of obtaining machinery (i.e., changing import controls, paperwork and financing) have prompted entrepreneurs to prolong the useful life of their equipment and adapt it to fulfill new needs.

Without additional data, however, we are unable to argue that the declining balance rate should be lower or higher than the 1.65 assumed. When we changed this assumption to 1.5 and 2 (the lower and upper limits most often used in the literature), this did not change our capital estimates significantly. In effect, these alternative assumptions form an upper and lower confidence band about our base case (See Table A.2). For a given capital

TABLE A.2

CAPITAL MEASURES BY YEAR, INDUSTRY, AND FIRM SIZE UNDER THREE DECLINING BALANCE RATE ASSUMPTIONS

Means and Standard Deviations (s.d.) in thousands of pesos

Capital Flow Measures	1977						1986					
	All Firms	Industry		Size by Employees			All Firms	Industry		Size by Employees		
		Agricul.	Kitchen	1-20	21-40	41+		Agricul.	Kitchen	1-20	21-40	41+
I. Depreciation = δ = 1.65/MSL												
p_K	317	295	351	121	457	485[a]	3199	3612	2754	2084	2925	5916[a]
(s.d.)	(284)	(246)	(339)	(71)	(350)	(242)	(2289)	(2893)	(1368)	(1395)	(1221)	(3664)
p_K (1977$P)							439	495	378	295	397	808[b]
(s.d.)							(318)	(403)	(190)	(202)	(159)	(528)
p_{vt}	568	505	662	213	749	944[a]	3714	3600	3837	2906	3096	6778[b]
(s.d.)	(578)	(513)	(666)	(149)	(601)	(568)	(2892)	(3389)	(2374)	(2794)	(1897)	(3672)
p_{vt} (1977$P)							518	514	522	455	462	776
(s.d.)							(444)	(420)	(486)	(579)	(280)	(524)
II. Depreciation = δ = 1.5/MSL												
p_K	328	307	359	126	469	503[a]	3402	3856	2913	2292	3083	6230[b]
(s.d.)	(294)	(256)	(347)	(73)	(359)	(252)	(2416)	(3047)	(1444)	(1534)	(1271)	(3908)
p_K (1977$P)							469[c]	531	402	326	420	854[b]
(s.d.)							(338)	(426)	(202)	(223)	(168)	(564)
p_{vt}	546	487	635	206	721	906[a]	3607	3483	3740	2806	3014	6591[b]
(s.d.)	(553)	(497)	(630)	(147)	(579)	(643)	(2807)	(3299)	(2290)	(2710)	(1858)	(3527)
p_{vt} (1977$P)							507	503	512	447	447	768
(s.d.)							(438)	(419)	(475)	(567)	(273)	(526)
III. Depreciation = δ = 2/MSL												
p_K	294	269	332	110	431	447[a]	2801	3140	2435	1690	2614	5286[a]
(s.d.)	(266)	(225)	(320)	(67)	(331)	(220)	(2040)	(2581)	(1232)	(1138)	(1139)	(3155)
p_K (1977$P)							380	425	331	236	350	714[a]
(s.d.)							(280)	(356)	(167)	(163)	(145)	(453)
p_{vt}	615	543	723	227	810	1031[a]	3943	3855	4037	3119	3274	7164[b]
(s.d.)	(638)	(549)	(754)	(151)	(653)	(766)	(3070)	(3586)	(2544)	(2952)	(1983	(4012)
p_{vt} (1977$P)							537	535	540	461	494	788
(s.d.)							(454)	(421)	(503)	(596)	(294)	(518)

Agricul.: agricultural implements; MSL : mean service life of firm capital equipment; p_K : aggregate measure of capital flow; p_{vt} : disaggregated measure of capital flow using Mohr's vintage rental price of capital formula; 1977$P: constant 1977 pesos. Means of respective groups (by year, industry, and size) are significantly different at the: a=.001 level; b-= 01 level; and c= at .1 level. Sources: firm survey data for 1977 (n=50) and 1986 (n=27).

measure, disaggregated or aggregate, the three alternative estimates of capital flows had zero order partial correlation coefficients of 99% and were significant at the .001 level.

Adjusting Capital Measures for Inflation

We described above the treatment of inflation with respect to the asset price of capital. However, given the rapid pace of inflation in Colombia, we had to adjust the data provided by the entrepreneur (interviewed during the first six months of 1978 and 1986) to December 1977 and December 1986 prices. We used the wholesale capital goods price index, provided by Colombia's central bank, to make these monthly adjustments. In the case of the aggregate measure of capital, we also used these indices to adjust 1986 figures to the December 1977 price level. In the case of the disaggregated measure of capital, we had sufficient information about additions and deletions to the capital stock and their relative prices in both years to be able to estimate implicit deflators. Table A.3 compares our implicit deflators with those published by the central bank.

TABLE A.3

COMPARISON OF DEFLATORS BY INDUSTRY AND FIRM SIZE

Means and Standard Deviations (s.d.)

	BdlR	Own Implicit Deflators derived from sample data					
Input or Output	Deflator	All	Industry		Number of Employees		
Item	12/77-86	Firms	Agricult.	Kitchens	1-20	21-40	41+
Capital goods	6.8	8.7	8.0	9.5	8.4	8.4	10.2
(s.d.)		(6.5)	(5.7)	(7.4)	(5.3)	(7.8)	(5.6)
-except buildings	6.7	10.6	10.1	11.0	7.1	10.5	16.8
(s.d.)		(10.6)	(11.9)	(9.1)	(4.3)	(9.4)	(18.4)
Unskilled labor	6.2	8.8	9.6	7.6[b]	9.0	8.9	8.0
(s.d)	(0.2)	(2.0)	(1.9)	(1.6)	(1.5)	(2.6)	(1.2)
Skilled labor	n.a.	6.5	7.2	5.8	8.3	5.4	5.8[b]
(s.d.)		(2.6)	(3.2)	(1.8)	(3.6)	(1.2)	(1.2)
Nonelectrical machinery	7.1	7.1	8.3	5.8[a]	7.6	6.7	7.2
(s.d.)		(1.9)	(1.5)	(1.4)	(1.8)	(1.9)	(2.3)

Agricult.: agricultural implements; kitchens: kitchen equipment; n.a. : not available. Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level; c= .1 level. Sources: BdlR (central bank) deflators: *Revista del Banco de la República*. The figure for unskilled labor corresponds to the CPI for blue collar workers and its standard deviation refers to the regional differences in this CPI.

The figures for the capital goods implicit deflator correspond to the disaggregated capital measure derived from Mohr's vintage rental price of capital formula. We do not present the deflator corresponding to the aggregate measure of capital. This deflator varies little since it does not reflect the differences in appreciation of different equipment; for all firms the mean was 7.3 with a standard deviation of only 0.33. As shown in Table A.3, our implicit deflators are higher than those estimated by the Central Bank for this broad class of goods. In terms of capital goods excluding buildings, the national deflator is closest to the implicit deflator for small firms. The lower rate of appreciation for these firms (although not statistically significant) reflects that their equipment was more heavily represented by the most simple cutting and welding tools. Our comparison of the value of assets in 1977 and 1986 showed lower rates of appreciation for the more simple machinery in contrast to more complex equipment i.e., lathes, milling and grinding equipment.

Our estimates of implicit deflators assume that from 1977 to 1986 there was little quality change in the capital equipment used by our sample of firms. This does not seem an unwarranted assumption given that with few exceptions, firms continued to use capital embodying a technology perhaps as much as 30 years old. Excluding a small firm which made significant additions to its capital stock by purchasing used Italian numerically controlled equipment, most firms continued to rely on basic universal metalworking equipment.

Table A.4 shows the pattern and magnitude of net changes in the capital stock by industry and size of firm. Although the average for all firms in the sample shows that net capital changes represented about one-quarter of their total capital stock in 1986, the high standard deviation shows wide variation across firms. For two thirds of surviving firms, one-third of their 1986 capital stock was acquired after 1977. Net changes in the capital stock in terms of 1986 replacement costs ranged from a reduction of $13.2 million by a large firm to $104.2 million in acquisitions of the small firm cited above. Accordingly, as a percentage of 1986 total capital stock, these net changes represented a reduction of 13% and an increase of 92%, respectively.

TABLE A.4

NET CHANGES TO CAPITAL 1977-1986

Means and Standard deviations (s.d.) in thousands of 1986 pesos

	All	Industry		Number of Employees in 1977		
Item	Firms	Agricult.	Kitchens	1-20	21-40	41+
Capital Flow:						
$-p_K$	828	1097	538	952	676	999
(s.d.)	(1284)	(1636)	(707)	(1756)	(668)	(1754)
$-p_{vt}$	1017	1158	866	1109	752	1540
(s.d.)	(1936)	(2260)	(1594)	(2166)	(739)	(3570)
Capital Stock	13572	18644	8110	19714	9357	13226
(s.d.)	(22473)	(29371)	(9868)	(34942)	(11154)	(20149)
Stock /Total%	26	27	24	33	22	24
(s.d.)	(26)	(26)	(28)	(30)	(25)	(27)

Agricult.: agricultural implements; kitchens: kitchen equipment; P_K: aggregate measure of capital flow; p_{vt}: disaggregated measure of capital flow.

Labor Input Calculations

As noted earlier, we derived two estimates of the labor input from our firm data. The first was physical measure in person day years of work for 1977 and 1986 based on the number of employees and the days worked per month as given by the entrepreneur. We took into account the following categories of labor: managerial (CEO and partners), administrative (or support staff), technical (engineers and other production professionals), skilled, semi-skilled, and unskilled. For our second measure with which we tried to account for the differing productivities of labor, we weighted the number of person days in each labor category by the ratio of that category's wage to the unskilled wage rate. For the managerial category, we assumed the average wage for management workers for the sector published in DANE's (Departamento Administrativo Nacional Estadístico) manufacturing survey. In the case of smaller firms whose entrepreneurs were former production workers, this estimate probably overestimated their wages. In the case of larger firms whose entrepreneurs were established industrialists, this probably underestimated their true compensation.

We also estimated the total wage bill later used in deriving our measures of profitability i.e., price cost margins. We made two important types of adjustments to the figures on wages and number of workers given by the entrepreneur at the time of the interview. The first adjustment follows the practice of Cortes, Berry and Ishaq (1985) to account for the likely changes in nominal wages during the survey years (1977 and 1986). Given that our yearly sales figures incorporated the price changes during the survey years and reflected the December 1977 and 1986 price levels, our wage figures estimated from daily or weekly wages given by the entrepreneur also had to reflect these monthly changes. To assure that our wage figures corresponded to the December price level of the survey year, we adjusted each firm's monthly wage bill by the rate of growth in nominal wages for the sector. For example, for a firm interviewed during the *i*th month the adjustment is as follows, beginning with December and working backwards to January of the survey year:

$$W_{12,t} = W_{i,t+1}\,(1+r_{12-i})$$

$$\vdots$$

$$W_{1,t} = W_{i,t+1}(1+r_{12-i,t+1})(1+r_{11-12,t})\ldots(1+r_{1-2,t})$$

where

t = *survey year* = *1977, 1986*
i = *month of interview during survey year*
W = *monthly wage bill (by skill category)*
r = *rate of growth of nominal wages for blue-collar workers in the non-electrical machinery sector between months denoted by subscripts*

The second adjustment involved a consistency check in which we compared the implied (or estimated) wage bill with the actual wage bill given by the entrepreneur. The implied monthly wage bill is the product of daily wages, number of workers, days worked per month for each labor category, and the percentage for fringe benefits. In a few cases we adjusted both the number of workers and their wage rate in order to make our implied wage bill consistent with the other information provided by the entrepreneur.

TABLE A.5

LABOR INPUT MEASURES BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in thousands of person days

Year/	All	Industry		Number of Employees		
Item	Firms	Agricult.	Kitchens	1-20	21-40	41+
1977:						
LPD	8.3	8.8	7.6	3.0	8.4	16.6[a]
(s.d.)	(6.6)	(7.4)	(5.1)	(1.2)	(1.5)	(6.0)
LUE	17.2	18.0	15.9	6.3	17.9	33.4[a]
(s.d.)	(13.6)	(15.0)	(11.5)	(2.9)	(3.8)	(13.6)
1986:						
LPD	7.3	8.3	6.3	4.5	6.8	13.9[a]
(s.d.)	(4.8)	(6.0)	(3.0)	(2.8)	(2.2)	(6.8)
LUE	12.4[b]	12.3	12.5	4.8	12.3	26.5[a]
(s.d.)	(8.8)	(9.3)	(8.7)	(2.0)	(3.6)	(9.0)

Agricult.: agricultural implements; kitchens: kitchen equipment; LPD: labor in unweighted person days; LUE: labor in unskilled equivalent person days. Means of respective groups (by year, industry, and size) are significantly different at the: a= .001 level; b= .01 level.

Table A.5 illustrates the two labor input estimates by year, industry, and size of firm. The person days physical measure yields only marginally different patterns from the unskilled labor equivalent measure; the zero order partial correlation coefficient is 86% for both years and significant at the .001 level.

Adjusting Labor Measures for Inflation

There was no need to adjust our physical measures of person days. However, in order to compare profitability trends from 1977 to 1986, we deflated the total 1986 wage bill including fringe benefits to December 1977 prices using the regional consumer price index (CPI) for blue collar workers published by the Central Bank's *Revista del Banco de la República*. By using these regional indices we hoped to more accurately capture the inflationary pressures faced by our firms located in four major regions. Table A.3 compares our estimates of implicit deflators for the labor input for unskilled and skilled workers with the published regional deflators which we used in our comparative analyses. The sample averages of these implicit deflators for these two types of labor categories suggest that the wages of unskilled workers increased faster than that of skilled workers.

Had we used these implicit deflators we would have assumed that workers in both years were of similar quality and productivity. Given the labor turnover in our sample of firms (average experience of workers with the firm was about 3 years for both survey periods; see Table 5A.4) and the improving access to education by a majority of Colombians, this would have been a questionable assumption.

VALUE ADDED CALCULATIONS

The estimates of value added begin with the yearly sales figures provided by the entrepreneur. We did not base our estimates of sales on the figures reported in tax declaration forms. We were well aware that some sales are not included to avoid the value added tax. After stressing the confidentiality of responses, we tried to get at the most accurate estimate of total sales. We first adjusted sales figures by the change in inventories to reflect as accurately as possible yearly gross output. For this purpose we had data on the value of inventories of finished products at the end of the survey year. Although similar data for the beginning of the year was not available, we estimated the likely change based on questions about the magnitude of inventory changes throughout the year. We did not have sufficient data about the quantities of the main products to be able to weigh each product's physical contribution to gross output by its price. The main problem with this unweighted procedure is that it assumes homogeneous output and thereby introduces a bias to the 1977-1986 comparisons. Given this implicit assumption of a constant product mix, we brought into our analysis information about the percentage of sales contributed by the main product and how this had changed since 1977 to try to account for the effects of changing product mix.

TABLE A.6

VALUE ADDED (VA) BY YEAR, INDUSTRY, AND FIRM SIZE

Means and Standard Deviations (s.d.) in millions of current pesos unless otherwise noted

Year/	All	Industry		Number of Employees		
Item	Firms	Agricult.	Kitchens	1-20	21-40	41+
1977:						
Value Added	4.4	4.9	3.5	1.2	3.7	10.0[a]
(s.d.)	(5.7)	(7.0)	(2.9)	(1.1)	(1.9)	(8.2)
VA Share (%)	52.5	50.0	56.2	51.4	58.4	48.5
(s.d.)	(15.2)	(13.6)	(17.1)	(16.5)	(15.3)	(11.8)
1986:						
Value Added	32.5	39.3	25.2	9.1	20.2	106.8[a]
(s.d.)	(59.9)	(77.4)	(34.3)	(7.8)	(12.1)	(118.9)
VA (1977$P)	4.8	4.4	5.2	1.2	3.3	14.9[c]
(s.d.)	(7.8)	(8.2)	(7.7)	(0.9)	(2.6)	(14.5)
VA Share (%)	51.4	49.2	53.9	49.1	51.9	54.4
(s.d.)	(13.0)	(12.9)	(13.1)	(13.5)	(14.4)	(8.7)

Agricult.: agricultural implements; kitchens: kitchen equipment; 1977$P: 1977 constant pesos. Means of respective groups (by year, industry, and size) are significantly different at the : a= .001 level; b= .01 level; c= .1 level.

The second step involved estimating value added. In the initial 1977 survey, CBI asked the entrepreneur to estimate the percentage of sales devoted to material and intermediate purchases, to services, to wages, and to gross profits where the latter two represented the share of value added. To derive value added we adjusted our estimates of gross output by the value added share and compared these figures with the estimates of the wage bill to assure the consistency across these measures. The resulting estimates are illustrated in Table A.6 above.

Adjusting Value Added for Inflation

In Table A.3 we presented a comparison of the national output deflators with those implicitly derived from our 1977-1986 firm data. We used our implicit deflators to adjust our 1986 values to the 1977 price level, basing these implicit deflators on information about the firm's principal product prices in the two survey years. After deriving the implicit deflator we examined the responses of the entrepreneur referring to the changes they had made in their products since 1977. If significant improvement had been made, our implicit deflator would overestimate the inflationary impact. However, none of the firms reported significant quality or design changes in their products, most described improvements to increase durability or aesthetics--the latter was relevant only to industrial kitchen producers. The types of improvements reported by one firm were also reported by other firms in the sample. Given that our analyses would compare firms against other firms in their industry, we did not attempt to correct for quality improvements shared by most of the sample. Although our failure to correct for less than major quality changes in value added raises the question of a potential bias in comparing performance between 1977 and 1986, we believe that this bias is small considering the nature of improvements reported by the firms.

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